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THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

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CONTENTS

Society Affairs

English Meeting, July 26-29 (3); Meeting of the A. I. M. E. in the Canal Zone (16); Necrology (17).

Discussion

The Strength of Cast-Iron Punch and Riveter Frames, A. L. Jenkins. James Christie, Walter Rautenstrauch, Frank I. Ellis, Henry Hess, Oberlin Smith, Wilfred Lewis, John S. Myers, S. A. Moss, George Westinghouse, E. J. Loring, The Author . . 1259
Gas Engines for Driving Alternating-Current Generators, H. G. Reist. P. M. Lincoln, The Author 1295
Freight Train Resistance, Edw. C. Schmidt. T. S. Bailey, Wm. G. Raymond, S. A. Moss, F. W. Dean, H. G. Stott, G. N. Van Derhoef, F. J. Cole, W. F. M. Goss, J. B. Blood, Lawford H. Fry, Robert Moore, H. Wade Hibbard, J. P. Clayton, F. W. Marquis, The Author 1295
Two Proposed Units of Power, Wm. T. Magruder. Wm. Kent, D. Dreyfus, H. G. Stott, I. Lundgaard, The Author 1313
Operating Experiences with a Blast Furnace Gas Power Plant, H. J. Freyn. Addition to paper, A. E. Maccoun, Joseph Morgan, H. G. Stott, E. A. Uehling, S. K. Varnes, H. G. H. Tarr, Edward Rathbun, C. W. Baker, E. P. Coleman, A. Bement, W. E. Syder, The Author 1319
Critical Speed Calculation, S. H. Weaver. Henry Hess, S. A. Moss, M. Nusim, The Author 1359
General Notes 1363
Personals 1365
Accessions to the Library 1367
Employment Bulletin 1369
Changes of Membership 1371
Coming Meetings 1378
Officers and Committees 1381

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The Society as a body is not responsible for the statements of facts of opinions advanced in papers or discussions. C55

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 SEPTEMBER 1910 NUMBER 9

THE JOINT MEETING IN ENGLAND

In his response to the address of welcome at the first professional session at Birmingham, of The American Society of Mechanical Engineers and The Institution of Mechanical Engineers, Dr. W. F. M. Goss, Vice-President of the Society, happily alluded to the spirit of federation that exists among English-speaking engineers and to the pleasure and profit to be derived from joint meetings of the two Societies. To say that this meeting afforded the greatest possible pleasure to the American visitors is but to state a fact, the true appreciation of which can be had only by those who were the recipients of the whole-hearted reception given by their English friends, their elaborate entertainment and provision for seeing the best that the country afforded, in industrial as well as historical features, and in its delightful social life.

THE OCEAN TRIP

The White Star steamship Celtic, bearing the party for the joint meeting, sailed from New York Saturday afternoon July 16 and arrived in Liverpool Sunday evening July 24.

The weather during the trip was good and the voyage was a time of rare enjoyment for the whole party. The ship's officers were gracious in their attentions and the committee of arrangements, Mr. Ambrose Swasey, chairman, had their plans perfected with the greatest care and conducted the party up to the time of arrival at Birmingham by special train, when the travelers were placed in the hands of their generous and attentive hosts.

Not the least contribution to the pleasure of the journey was the program of the entertainment committee, Mr. Geo. M. Brill, chairman, which provided for games of bridge, deck games and tournaments, inspection trips about the boat and the following evening events:

Monday Evening, July 18 Reception

By the officers and past-presidents of the Society and chief officers of the ship.

Tuesday Evening Illustrated Address

By Worcester R. Warner, past-president, on What are the Astronomers doing.

Wednesday Evening Musicale

Thursday Evening Illustrated Address

By John R. Freeman, past -president, on Construction of the Panama Canal.

Friday Evening Dancing

Saturday Evening Informal Entertainment

Awarding of prizes for the games, tournament, etc.; music; a humorous address by James M. Dodge, past-president; and original poems by others.

The sailing list of the Society comprised over 150 members and guests who were joined by upwards of 100 others at Birmingham and London. There was deep regret that it had been impossible for President and Mrs. George Westinghouse to accompany the party and participate in the events to which their presence would have contributed so large a measure of completeness.

On the last Saturday of the trip the appreciation of courtesies extended by the ship's officers was shown by presenting Capt. A. E. Hambelton of the Celtic with a beautifully engraved silver box for cigars and chief-engineer C. C. Lapsley with an electric desk lamp.

As the boat approached Liverpool it was boarded by President John A. F. Aspinall and other prominent members of the Institution of Mechanical Engineers and representatives of the city of Liverpool, who extended a cordial welcome to the visitors, to which Vice-President W. F. M. Goss responded for the Society.

FIRST PROFESSIONAL SESSION

The first regular session of the joint meeting was held Tuesday morning at the Birmingham and Midland Institute. The two societies were welcomed to the city by the Lord Mayor of Birmingham (Alderman W. H. Bowater) who spoke of the importance of Birmingham as an engineering center and of the interest which the visitors would have in the various plants. The Institution of Mechanical Engineers was founded in Birmingham at the old Queen's hotel, then the terminus of the London and Northwestern Railway, and it was doubly appropriate that the first of these meetings should be held in that city.

Mr. George Tangye, a vice-chairman of the Birmingham reception committee and custodian for the city of the Boulton and Watt relics, said it was his privilege to offer for the acceptance of the American visitors a letter dated 1777, signed by James Watt and addressed to Mathew Boulton, his partner, as a memento of their visit to Birmingham. Although he had presented all the relics to the city and was now merely their custodian until such a time as a suitable place should be found for them, he was sure the gift was made with everybody's approval.

This letter was written on both sides of the paper and framed so that the two sides of the sheet can be read. It bears the inscription, "Presented to The American Society of Mechanical Engineers by George Tangye at the Joint Summer Meeting at Birmingham in July 1910."

President Aspinall, in acknowledging the welcome of the Lord Mayor for the Institution of Mechanical Engineers, said it was fitting that the meeting should be held in a city so closely associated with engineering work and tradition. There is a close connection between Boulton and Watt and their American cousins. A few months ago the Americans were celebrating the opening of the Hudson River to steam navigation and Robert Fulton bought his first engine from Boulton and Watt. Therefore Birmingham had played an important part in the development of engineering on both sides of the Atlantic. He reminded the meeting that the first man to spin cotton without the aid of human hands was a Birmingham man, John Watt, who began his experiments in 1730 and in 1741 was entirely successful. In the museum at Birmingham is the first hank of cotton spun by machinery. Engineers recognize how much they owe to Birmingham.

Dr. W. F. M. Goss on behalf of The American Society of Mechanical Engineers said they came joyfully to Old England because many of the practices of their profession had their beginning in Birmingham. Here the implements were made with which many of the pioneers of America furnished their homes, cultivated their ground and equipped their mills. Although Watt and Boulton worked in the highlands of England, they in America shared in the output of their factory. The Society was proud to be the guest of an institution whose first president was George Stephenson. At the present day the engineer had become the world's great civilizer. For the rush light he had given electric illumination and for the stage-coach the express train. He had given men new occupations and in the transforming process the engineers of England and America had each played their part. Only an ocean lay between them and thanks to English shipbuilders this was no longer a barrier, but a means of communication. The maintenance of their respective traditions would doubtless always require separate organizations, but they might readily federate the spirit of the organizations, to which end this meeting would contribute. The joint meeting, the good fellowship which will inevitably come out of it, the pleasure which the Americans as cordially-welcomed guests are to enjoy, were sure to prove contributing factors in the working out of such a result. He expressed the sincere thanks of the Society for the gift of the Watt memorial by Mr. Tangye. Americans had admired the beautiful marble memorial of that great engineer in Westminster Abbey and they would doubly admire a gift which was a fragment of Watt's own work.

Following these formal addresses President Aspinall took the chair and proposed that a cablegram be sent to George Westinghouse expressing the regret of the Institution at his absence. The Secretary read the minutes of the last meeting of the Institution, the election of candidates was announced, and the meeting then proceeded to the discussion of the professional papers which were devoted to the general subject of Handling Locomotives at Terminals. The first paper offered was by Cecil W. Paget, Mem.I.M.E., general superintendent of the Midland Railway, on English Running-Shed Practice, corresponding to American enginehouse practice. The paper described running sheds as built in England, consisting of two types, with the tracks laid parallel and with tracks radiating from a central turntable. The straight sheds are economical in first cost and maintenance, but unless of the type known as "through sheds" they are awkward to work; while the latter class are draughty. The paper discussed the equipment of running sheds, including shear legs for lifting engines, lighting, arrangements for washing out, water softening, methods of coaling, etc. It then took up running-shed arrangements, and examinations of engines. This paper, in common with the other English papers presented at the joint meetings, has been sent to the membership of the Society.

There were four American papers on this subject as follows: Handling Locomotives at Terminals, by Frederic M. Whyte; Engine House Practice, by F. H. Clark; American Locomotive Terminals, by William Forsyth; and Handling Engines, by H. H. Vaughan. These papers have been published in The Journal, and were presented in abstract at the meeting by F. H. Clark. They dealt systematically with the subject of the meeting, the first discussing briefly the different phases of the whole subject, including the location and layout of a terminal, the organization and method of conducting the work at a terminal and pooling locomotives and crews. Some years ago it was general practice to assign a locomotive to a crew and both crew and locomotive to particular runs. The plan was later developed to increase the service of locomotives by placing any crew on any locomotive instead of holding the locomotive until its assigned crew could obtain the necessary rest.

The paper by Mr. Clark considered in detail terminal design and the handling of locomotives to secure continual operation. Mr. Forsyth described a particular terminal, that of the Pennsylvania Railroad at East Altoona, including the organization of the plant. Mr. Vaughan discussed the question of pooling, concluding that in passenger service it was objectionable, while in freight service it was advisable if conditions were such that engines could not be run with assigned crews.

These papers were discussed by George Hughes, President J. A. F. Aspinall, Jas. M. Dodge, Henry Fowler, H. L. Gantt, A. D. Jones, and Jas. E. Sague. During the discussion the chair was vacated by President Aspinall and taken by Dr. Goss. The discussion upon these and other papers presented at the joint meeting will be published in a later number of The Journal.

THE SECOND PROFESSIONAL SESSION

At the opening of the session on Wednesday President Aspinall announced the receipt of a cablegram from President Westinghouse in reply to the one sent him, expressing his regret because of his absence from the meetings and the highest hope that the joint meeting would be of permanent value in cementing the relations between the societies and in promoting coöperation between the engineers of the two countries.

Dr. Goss was then asked to take the chair and a paper was read on High-Speed Tools and Machines to Fit Them by H. I. Brackenbury of Newcastle-on-Tyne, Mem.I.M.E. This paper considered the characteristics of high-speed tools and of the steels of which they are made and discussed machine tools for the use of such steel. It compared machine design before and after the introduction of high speed tools and laws regarding the weight and power of machines. There were data on the cost of machining and on the power required for cutting, with numerous excellent examples of rapid production.

Following this a topical discussion was offered by three American members. Mr. John Calder gave examples, illustrated by lantern slides, of rapid production in machine tool work, the data having been contributed by some twenty-five different firms and machine tool builders. It covered subjects of heavy lathe-work, including tire and axle turning, milling, gear cutting, turret-lathe work and grinding.

Mr. Luther D. Burlingame followed with an account, also illustrated by lantern slides, of examples of work done in the shops and on the tools of the Brown & Sharpe Mfg. Company. He showed illustrations of jigs, and tools used with them, to indicate the complexity of modern manufacturing methods. He also gave tables of limits indicating the degree of precision to be attained in grinding for running and force fits.

Mr. L. P. Alford presented a resumé of the most recent accomplishments in heavy drilling by the use of high-speed drills, driven by tools especially designed for rapid production.

Discussion was offered by J. Hartley Wicksteed, William Lodge, Dempster Smith, Walter Carter, Fred. W. Taylor, Frank B. Gilbreth, President Aspinall, and Alexander Taylor (read by the secretary).

The subject of tooth gearing was then considered, a paper first being presented by J. D. Steven of Birmingham, Mem.I.M.E., in which different methods of cutting gear teeth were discussed and different systems of tooth design were compared, with the conclusion that conditions have so radically changed during the past two years that there is every reason to consider the question with an open mind. If a new form of tooth is desirable, he believed that a stub tooth with 20-deg. pressure angle would be a change in the right direction, because it can be used in its true form down to 12 teeth; it is a stronger form and most commonly used; and a large proportion of its face does useful work.

Mr. Wilfred Lewis, Mem.Am.Soc.M.E., read a paper on Interchangeable Involute Gearing, prepared at the request of the Meetings Committee as a discussion on the subject, but not necessarily expressive of the opinions of the Gear Committee of which he is chairman. He, however, outlined the investigations of the committee up to the present time and gave drawings of the gear testing machine which had been designed for testing gears of different types and which is now being used for the purposes of the committee under the direction of Professor Lanza at the Massachusetts Institute of Technology. The paper illustrated the shapes of teeth to be tested which include teeth of different obliquities. Mr. Lewis advocated a pressure angle of 22½ deg. and an addendum of seven-eighths module.

These two papers were discussed by P. V. Vernon and Luther D. Burlingame; a written discussion contributed by C. R. Gabriel, member of the Gear Committee, and read by Secretary Calvin W. Rice, argued for the Brown & Sharpe 14½-deg. standard, with modified tooth to avoid interference, as the most practical and useful form for present-day conditions.

After this discussion a resolution was offered thanking the hosts and people in and around Birmingham for the hospitality extended to the members of the two Institutions.

ENTERTAINMENT AT BIRMINGHAM

Every convenience was provided at Birmingham, as well as later at London, in the way of provision for mail, telegraph, telephone and messenger-service, offices for the transaction of business, and the leading clubs extended invitations to the visitors to share in the club privileges.

Luncheon was served in the Town Hall at the close of each of the professional sessions.

The chief event during the stay was the garden fête, on Tuesday evening in the Botanical Gardens at Edgbaston, by invitation of the Birmingham reception committee. The grounds were beautifully illuminated with fairy lamps and Japanese lanterns. There were 10,000 of the many-colored little lamps and 1000 Japanese lanterns strung on frame work of bamboo. The conservatories were used as a place of assembly and for the reception at which the Lord Mayor and Lady Mayoress (Alderman and Mrs. Bowater) and members of the Birmingham reception committee received. Music was furnished by the band of the Royal Marines from Portsmouth and during the evening there was a display of fireworks which closed with a set piece showing the British and American flags crossed. The fête was most picturesque in its settings and an occasion of unusual pleasure to those in attendance.

Numerous excursions were made on Tuesday afternoon to places of interest in the vicinity of Birmingham. Among these was one to the testing-station of the Pump & Power Company at the South Staffordshire Mond Gas (Power and Heating) Company's at Dudley Port, Tipton; the works of the Austin Motor Company; the Metropolitan Amalgamated Railway, Carriage and Wagon Company, Saltley; and the Frankley filter-beds of the Corporation Water Works; while some went to Stratford-upon-Avon, Worcester, Stoneleigh Park, and Kenilworth.

A number took advantage of the invitation of Mr. George Tangye to visit the Watt room at his residence, Heathfield, where are located the Watt relics which are preserved as nearly as possible in the way the famous engineer left them.

On Wednesday afternoon the new buildings of the University of Birmingham were visited. The company was cordially welcomed by the principal, Sir Oliver Lodge and Vice-Chancellor Alderman C. G. Beale. The original buildings of the university are in Birmingham and the new buildings, recently finished and equipped are located outside at Bournbrook on a site of ample area and contain departments for the study of several branches of engineering. The university is of peculiar interest to Americans as it represents the latest developments among English institutions for technical training. The equipment was selected only after an extended study of both American and European universities and is aimed to be evenly balanced in the various departments rather than providing for specializing as in certain of the American schools of engineering.

The concluding event in Birmingham was a reception at the Council House on Wednesday evening, attended by about 1000 guests, at which the Lord Mayor and Lady Mayoress and various city officials received. There was music and a collation; and addresses expressing gratitude to the Lord Mayor and Lady Mayoress were made by President Aspinall and Dr. Goss, thanking them for the extraordinary kindness displayed in the visit of the engineers and their friends to the city. The Lord Mayor replied, humorously expressing his own gratification that the efforts of the people of Birmingham to entertain their guests had been so much enjoyed.

PROFESSIONAL SESSION AT LONDON

The third professional session was held in the rooms of the Institution of Civil Engineers, London, the subject for discussion being the Electrification of Railways. In the unavoidable absence of Mr. James C. Inglis, president of the Institution, Mr. Alexander Siemens, senior vice-president, welcomed the members of the two Societies.

President Aspinall in replying expressed his gratification that the meeting could be held in the present building of the institution, because a new building was shortly to be erected and when their American friends paid their next visit to England they would be able to inspect the new home of that institution. Dr. Goss also fittingly responded.

Of the papers presented, that by George Westinghouse on the Electrification of Railways compared the present status of electrification to the conditions existing some years ago in this country when railroads used different gages of track, preventing interchange of rolling stock and the operation of through trains. Different roads are now employing different systems of current supply in their electrification projects which will eventually interfer with the transfer of traffic from one road to another. The author called attention to the danger of this practice and pleaded for the adoption of a uniform system before electrification is extended far enough to bring about the difficulties mentioned. In this connection he summarized by the use of tables, diagrams and photographs the advantages and disadvantages of the direct current, three-phase and single-phase systems and outlined the operating experiences of various railroads, both in this country and abroad, with the use of these systems.

W. B. Potter, Mem.Am.Soc.M.E., discussed in his paper on Economics of Railway Electrification the commercial and economic considerations governing the electrification of railways, outlined the relative advantages of steam and electricity and considered the conditions of operation with various requirements of service as affecting the problem. He believed that the use of the 1200-volt direct-current system for interurban railroads will greatly increase and anticipated the entire discontinuance of the single-phase system.

The Electrification of Trunk Lines, by L. R. Pomeroy, Mem. Am.Soc.M.E., discussed this subject from a commercial standpoint and contained calculations as to the relative cost of steam and electric operation. Examples were worked out in detail for specific cases.

The Electrification of Suburban Railways by F. W. Carter, Mem. I.M.E., discussed the present and future of electrification in England, with particular attention to the conditions affecting suburban service. The author saw little prospect of general electrification in England, as no advantage is apparent which would justify the expense. Only in the case of heavy suburban service is there any commercial advantage accruing from electrification.

H. M. Hobart, Mem.I.M.E., in his paper on The Cost of Electrically-Propelled Suburban Trains, treated in considerable detail the various factors which enter into the cost of electric suburban service and their influence on the choice of a system of current supply.

These papers were discussed by H. F. Parshall, J. Dalziel, Sidney Stone, Charles F. Scott, H. M. Hobart, Angus Sinclair, J. G. Wilson, F. R. Hutton, F. W. Carter, H. H. Barnes and President Aspinall.

ENTERTAINMENT IN LONDON

The whole day Thursday was devoted to excursions, three trips being provided for. The first of these was to Coventry and Rugby with an opportunity to visit the Daimler works and the plants of Alfred Herbert, Willans and Robinson, and the British Thompson Houston Co. Most of the ladies went to Kenilworth, Warwick, and Stratford-upon-Avon. The other excursion was to Litchfield.

Thurdsay evening there was a conversazione at the Institution House at Storey's-gate, St. James Park, Westminster. President and Mrs. Aspinall received and a brief lecture was given by Dr. Hele-Shaw on the subject of the Stability of Aeroplanes and the Theory of Stream Lines, which was illustrated by lantern slides having glycerine forced between glass plates, giving a most beautiful effect.

On Friday afternoon there were garden fêtes given by Wm. H. Maw, past-president, and Mrs. Maw, and Sir John Thornycroft, member of the council, and Lady Thornycroft. Visits were also arranged for those who cared to go to the museum of the Public Record Office and to the Times Office.

On Saturday, two excursions were arranged taking the entire day, both covering the same ground but in different directions. These were to Windsor and Marlow. Part of the trip was by special train and part by launches on the Thames. All had an opportunity to visit Windsor Castle under the guidance of the Mayor of Windsor, Councillor C. F. Dyson and several members of the Institution. Luncheon and tea were served and the trips were regarded by many as the most beautiful of the whole meeting.

In the evening there was an opportunity for a visit to the Japan-British exhibition at Shepards Bush and to the Garden Club.

On Sunday afternoon a visit was made to the Zoological Gardens in Regents Park and in the evening a company assembled at Westminster Abbey to inspect the Baker Memorial Window and later to attend the service in the Nave, places being reserved for the visitors.

The members of the Society were especially interested in the window because the Society had contributed towards the erection of this memorial to the memory of a man who possessed such remarkable engineering ability. It is the first time in Europe that a full and satisfactory recognition of the execution of engineering work has been so appropriately honored.

THE INSTITUTION DINNER

The social functions of the joint meeting were brought to a close on Friday evening in the Connaught Rooms. The loyal toasts having been drunk with enthusiasm, Mr. Aspinall gave The Health of the President of the United States and Ambassador Reid responding, said that he was there to recognize the peculiar fitness of a toast to the President of the United States from the great profession which had wrought these marvelous advances of our modern life, and was still carrying on the high tradition of its earlier years.

Sir William White, proposing The American Society of Mechanical Engineers recalled the fact that it was founded but thirty years ago and now it had a membership of about four thousand. The English Institution was founded in 1847. With common objects and common ideals, with a common desire to do their duty in the cause of humanity, they, as the years rolled on, were being drawn closer together, both furthering the cause of civilization and all that made for the good of humanity, and bringing the nations together in happiness, brotherhood and peace. In the maintenance of law and order, and the repression of rebellion and wrong, the mechanical engineer bore a prominent part, and the cause of liberty and truth owed much to him.

In acknowledging the toast, Professor Hutton, honorary secretary of the Society, asserted amid general applause, that Americans honored King Edward, and with Englishmen mourned his death, because they recognized in him a man, self-sacrificing and self-immolating, when by immolating himself, he could advance the interests of his great Empire. The present gathering was one of more than merely good friends. It had an inner and broader significance. It was the culmination of a series of meetings of the mechanical engineers from both sides of the Atlantic, and mechanical engineers were potent factors which underlay the civilization of the Anglo-Saxon race. The American was so much at home in the United Kindgom, because he and his host had a common ideal. As long as they had that ideal their civilization rested on a bed-rock so massive that there was no force which could ever shake the nations apart.

Our Other Guest was given by Mr. Edward B. Ellington, vice-president of the Institution and replied to by Dr. Glacebrook. Success to the Institution was proposed by Dr. Goss, and acknowledged by the president.

A NOTE OF COMMENT

Of the entertainment provided the American engineers, it can only be said that the Americans were literally overwhelmed with the courtesies extended with the preparation made for their pleasure. Collations, luncheons or teas, were served on every occasion and there was arrangement even to the extent of cab and omnibus conveyance. Not only were the excursions for members and guests conducted on most liberal plans, but the ladies' committee provided a special program of most entertaining visits and various other functions that added much to the delight of the lady guests.

A word should be said about the printed matter supplied by the Institution. A program of over thirty closely-printed pages was issued, filled with information most likely to be desired by the visitors, together with a series of finely executed maps of the principal places to be visited with the points of interest and the places where members were to assemble specially indicated. A souvenir was issued by President Aspinall as a memento of the joint meeting containing beautifully executed portraits of the presidents of the two societies of Stevenson, Boulton, Watt, Trevithick, Fulton and Symington. There were interesting anecdotes and quaint illustrations relating to early events in engineering compiled from various sources, together with a photograph of the first hank of cotton spun by John Wyatt.

A VOTE OF THANKS

At the conclusion of the last professional session a vote of thanks was given by the members of The American Society of Mechanical Engineers, the text of which follows:

The American Society of Mechanical Engineers, present by invitation at the closing session of the joint summer meeting of 1910 with the Institution of Mechanical Engineers asks permission to offer for record the following minute and requests its acting president to put the resolution to vote:

The American Society of Mechanical Engineers has been enveloped in an atmosphere of courteous, friendly and devoted attention from the moment that the vessel which carried the official and organized party entered the River Mercy at Liverpool. Beginning with the reception on the steamer, at which the president and secretary of the Institution officially welcomed the party, in conjunction with representatives of the city and other interests of that progressive corporation, and continued through the arrangements for comfortable and convenient transportation by train to the place of first meeting, providing on arrival for ample and satisfactory hotel accommodations and for organizing in a masterly way, which extended even to the most minute detail for the enjoyment of the visitors, in affording opportunities to visit works over the city, for transportation, and for motor drives in the historic midlands of England, the Institution of Mechanical Engineers has placed The American Society of Mechanical Engineers under an obligation which no mere words or resolutions are an adequate medium to discharge. The visitors can only assure the home Society, its president, its council, its secretary and its organizing committee, that just because they are themselves organizers and doers, they are able most thoroughly to appreciate such work well done.

The American Society also appreciates most sincerely the generous purpose which has spared no sacrifice when the desired object of the hosts has had to be met by the ordinary commercial procedure as respect outside parties. Hence, the Society moves and seconds the following resolution:

Resolved: That The American Society of Mechanical Engineers desires, in addition to the resolutions passed in Birmingham thanking those who had put both bodies under a pleasing debt of obligation, to put on record certain special resolutions of thanks.

Resolved: That The American Society thanks the Institution of Mechanical Engineers, its president, council, secretary and committee for their ceaseless, unremitting and painstaking labor for the pleasure and success of the joint meeting of 1910 in Birmingham and London.

Resolved: That this joint meeting will be a memory of delight and pleasure for all the Americans who have been privileged to share in it.

Resolved: That The American Society of Mechanical Engineers desires to thank the Birmingham Reception Committee for certain special considerations at their hands which were extended exclusively to the American members of the joint party and requests the Institution to be the channel for conveying such action of thanks.

Resolved: That The American Society of Mechanical Engineers desires by this action to express for the ladies who have accompanied the members something of the appreciation of both members and ladies for the delicate and considerate attention which has made their participation a delight and a possibility; and the members feel that any international friendships springing from these days of close association are sure to last forward into happy future years.

Resolved: That The American Society of Mechanical Engineers requests the Institution of Mechanical Engineers to incorporate this minute and action as part of it record of the the proceedings of the joint summer meeting of 1910.

MEETING OF THE A. I. M. E. IN THE CANAL ZONE

The members of this Society have been invited to join with the American Institute of Mining Engineers during their visit to the Canal Zone, October 21 to November 15, so far as accommodations will permit. The party sails from New York on October 21 on the Hamburg-American liner Prinz August Wilhelm, touching at Havana and Kingston en route to Colon. A full week will be spent in the the Canal Zone, during which time the party will inspect the work on the canal in addition to holding professional sessions. The cost of the trip, including berth and meals on the steamer, railroad transportation, meals and accommodations at the Hotel Tivoli in the Canal Zone, will be $200. This rate holds good until September 20, after which an additional charge of $50 will be made by the steamship company. Further details regarding the arrangements for the trip may be obtained from Dr. Joseph Struthers, Assistant Secretary of the Institute.

NECROLOGY

JOHN DENISON EVARTS DUNCAN

John Denison Evarts Duncan, Life Member of the Society, was born at Union Falls, N. Y., July 26, 1871. His preparations for his university course was in the high school of Ann Arbor, Mich., and in 1893 he was graduated from the University of Michigan with the degree of B.S. in electrical engineering and in 1894 from Cornell University with the degree of M.E. From 1894 to 1896 Mr. Duncan was employed by the Terre Haute Street Railway Company, Terre Haute, Ind., and the Stanley Electric Manufacturing Company, Pittsfield, Mass. With the latter company he was associated with Mr. Stanley and Mr. Chesney in their extensive experimental work connected with the solving of the early high tension problems which were first studied and worked out at their factory. On leaving the Stanley Electric Manufacturing Company, Mr. Duncan successively held positions in New York with the Metropolitan Street Railway Company; the Western Electric Company; the New York Telephone Company; Westinghouse, Church, Kerr and Company; and the Consolidated Railway Electric Lighting and Equipment Company. In 1901 Mr. Duncan entered the employ of Sanderson and Porter, 52 William Street, New York, and in 1903 was sent to Portsmouth, N. H., by his firm to construct a 1000-kilowatt power station for the Rockingham County Light and Power Company. At the time of his death, July 13, 1910, he held the position of managing engineer with the same firm. While directing the engineering work of this firm Mr. Duncan was in responsible charge of the design and execution of many large and diversified projects and well earned the high esteem and confidence of his employers, associates and friends in engineering and business circles. All who knew him and his work recognized his versatility, sound judgment and exceptional ability.

Mr. Duncan was a member of the American Institute of Electrical Engineers, the Brooklyn Engineers Club, the Engineers Club of New York, the Machinery Club of the City of New York, the Michigan Club of New York, the University of Michigan Club, and the Cornell University Club of New York.

JAMES B. FAULKS, JR.

James B. Faulks, Jr., was born December 13, 1873, at East Orange, N. J. After his early education in the public schools, he attended the Bordentown Military Institute and later entered Stevens Institute of Technology from which he was graduated in 1896 with the degree of M.E. He held during his lifetime many positions of prominence in engineering work, among which may be mentioned that of draftsman with the Standard Air Brake Company, of engineer of tests with the Edison Electric Illuminating Company, of designer with the Harrisburg Foundry and Machine Works and also with the Crocker-Wheeler Company and of mechanical engineer with the New York Safety Steam Power Company. He was also prominent in connection with experimental work on the Roumaine Cultivator, and was identified with research work in gas engines. In 1904 Mr. Faulks accepted a position at Syracuse University as an instructor in the L. C. Smith College of Applied Science, and at the time of his death, July 14, 1910, was professor of experimental engineering in the same college.

Professor Faulks was a Junior Member of the Society and also a member of the Technology Club of Syracuse.

WILLIAM W. SNOW

William W. Snow who died at his home in Hillburn, N. Y., April 26, 1910, was born at Heath, Franklin County, Mass., July 17, 1828. At fifteen years of age he took up the book-binding trade, but at the end of three years left it to become assistant civil engineer with the Worcester and Nashua Railroad. In 1848 he went to Woonsocket, R. I., and for the five succeeding years was employed in the foundry at that place, when he accepted a position as superintendent of the Indianapolis City Foundry. In 1856 he established a factory at Newburgh, N. Y., for the manufacture of car wheels. This business was successfully carried on under the general management of Mr. Snow until 1859, when he withdrew his interests to become general manager of the Union Car Wheel Works, Jersey City, N. J. In 1866 Mr. Snow came to Ramapo, N. Y., and with others organized the Ramapo Wheel and Foundry Company, of which he was made general manager and superintendent and finally president. In 1881 he organized the Ramapo Iron Works in Hillburn, N. Y., a village founded by himself. Nine years later he began the erection of commodious buildings in Mahwah and installed therein the Ramapo

Iron Foundry Company. He was the president of this company until its consolidation with the American Brake Shoe and Foundry Company when he became chairman of its Executive Board, which position he held at his death.

In 1895 Mr. Snow was appointed by Governor Morton one of the New York State commissioners to the Atlanta, Ga., Exposition. He joined this Society in 1889 and was also a member of clubs in Boston Philadelphia and Chicago. He was well known in European circles as one of the most prominent manufacturers of this country.

WILLIAM E. CRANE

William E. Crance died on May 22, at Duluth, Minn., after a short illness. He was born in Burlington, Conn., and received his early education at the local schools. At fourteen years of age he began to apply himself to engineering and two years later took charge of a small engine at Bristol, Conn. He later went to Waterbury where for twenty-five years he was connected with the Benedict and Burnham Company as chief engineer. After severing his connection with this firm he became consulting engineer for the New England Engineering Company and designed several power plants of considerable importance, notably, that of the Kings County Electric Light and Power Company, the Passaic Electric Light and Power Company and the Albany and Hudson Railway Company. Later he was chief engineer at the Hotel Astor in New York City, but failing health forced him to resign and seek the climate of Minnesota.

Mr. Crane was a member of the National Association of Steam Engineers as well as of this Society, which he joined in 1887. He was the author of a treatise on American Stationary Engineering and had the distinction of being the first man to use the double eccentric on a Corliss engine. In addition to his engineering activities he took a keen interest in public affairs and contributed much to the press on social conditions.

THE STRENGTH OF CAST-IRON PUNCH AND RIVETER FRAMES

By Prof. A. L. Jenkins, Published in the Journal for May 1910

ABSTRACT OF PAPER

A brief résumé is given of the important theories proposed for the analysis of stresses in straight cast-iron beams. The examination of the various formulae proposed for curved beams shows that certain assumptions made in their derivations are not true for cast iron. Tests on small castings, similar in shape to punch frames, failed to verify any given formula. The relation between the strength of frames and the test bars cast with them is approximately represented by the ordinary formula for straight beams subjected to combined bending and tension. A criticism of the Résal and Pearson-Andrews formulae states that they are not true for cast iron, are unwieldy in their application and involve considerable chance of error. Some of the castings failed in a very peculiar manner, and under a load much smaller than that predicted by the formulae, which suggests the advisability of investigating such machine parts by a different method. The writer claims that calculations based on the load-deflection curve drawn by an autographic recorder on a testing machine are of no value.

DISCUSSION

James Christie. The experiments of Professor Jenkins show the existence of serious stresses at the junction of thick and thin sections of the castings. This accounts for the failure of specimens Nos. 4, 5 and 12 at test loads one-third less than for specimens Nos. 6 and 14, whereas the estimated resistance of the latter, due to increased web thickness, is only 10 per cent greater than the former. Fairbairn and Hodgkinson observed this fact in their experiments during the middle of the past century, and aimed to obviate it by gradually tapering the thick into the thin sections, a practice of experienced designers today. Indeed, the same lines of weakness have been observed in rolled sections, illustrated in the tests of rolled I-beams by Professor Marburg.[1]

2 It is generally believed that these internal stresses are relieved by molecular adjustment in course of time. The author does not in-

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[1] Vol. IX, Proceedings of the American Society for Testing Materials.

form us what time elapsed between the casting and testing of his specimens. If the time was quite brief, satisfactory results could not be expected from the tests.

3 The writer desires to direct attention to what he believes to be a secondary stress occurring in the frames of tools of this class, and if the views hereafter stated are incorrect, desires to be corrected.

4 In clamps shaped like *A* in Fig. 1 it has been observed that when the back of the clamp is weak as compared with the arms, the back deflects inward when the clamp is subjected to a distending force at the ends of the arms, making the piece assume the shape *B*. A similar tendency has been noticed in punching machines with a weak back or spine, indicating that the flexure inward of the beam forming the spine of the frame arises from the distending force applied at the outer end of the arms. This force acts through lever arms whose length can be taken as the distance from the neutral axis or center of gravity of the spine to the end where the force is applied and is resisted by the beam of the spine whose length may be taken as the distance between the neutral axes at the junction of the arms and the spine, or resisting lever arms half the length of this beam.

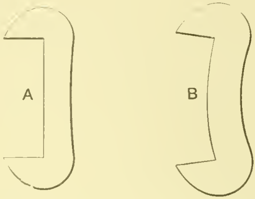


Fig. 1 Deformation of Clamp under Stress

5 This inward-acting transverse stress can be directly resolved into its resultant flange stresses. The resultant tension on the inner flange is believed by the writer to be independent of and supplementary to the tension of the same flange resulting from the direct action of the applied stress acting through the lever arms of the frame.

6 Let us test this assumption by applying it to the author's specimens Nos. 6 and 14 with the web 0.93 in. thick. From a practical point of view, in computation it is unnecessary to resort to the tedious process of calculating the flexural moments of the section, with all the doubts involved, especially when considering unsymmet-

rical sections of cast iron. By adding one-sixth of the web area to the flanges we can deal with the latter alone and proceed by the simple and direct law of the lever. When considering rupture in cast-iron beams, tension flange alone can be regarded, as rupture usually starts in the tension flange, irrespective of the magnitude of the compression flange.

7 It is good practice to assume the ultimate tensile strength of ordinary cast iron at from 15,000 to 18,000 lb. per sq. in. according to the thickness of the metal, and in consideration of the unequal distribution of stress through beam flanges. For specimens Nos. 6 and 14 the average unit resistance of the tension flange is assumed to be 18,000 lb. per sq. in. of section, the effective flange area is 3.54 sq. in. and total flange resistance 63,720 lb. The positive lever arm from the point where the stress is applied to the center of the back flange is 12.55 in. and the resisting lever arm or distance between inner and outer flange centers is 4.25 in. Calling the testing stress applied X, $\frac{12.55\ X}{4.25} = 2.95\,X =$ the stress on the inner or tension flange resulting from this source alone.

8 Considering the secondary stresses, the positive lever arm as heretofore denoted would be 9.5 in. long, and the effective beam length of the spine would be about 6.5 in. long. From these we have $\frac{9.5\ X}{3.25} \times 2 = 5.85\ X =$ the transverse stress acting inwards on the spine. Resolving this as before by simple leverage gives $\frac{2.92\,X \times 3.25}{4.25} = 2.23\ X$ as the resulting secondary tension on the inner flange. Hence, $2.95\,X + 2.23\,X = 5.18\,X =$ total tension in the flange or $X = \frac{63720}{5.18} = 12{,}300$ lb., which agrees closely with the ultimate test load obtained by the author on specimens Nos. 6 and 14.

9 Referring to Fig. 1 of the paper, specimens Nos. 1, 2 and 3, whose back or spine are rectangular in section, 4 in. by 2.5 in., assume this to be modified into a flanged section, for simplicity of computation only. It can be shown that the ultimate transverse strength of a cast-iron beam of rectangular section is identical with that of an equal flanged section of the same depth and sectional area, when the flange widths are about seven-eighths of the depth of the beam and the web

a minimum. This modification gives a tension flange, $3.5 \times 1.43 = 5$ sq. in., and 2.57 in. between centers of flanges, which is the resisting lever arm. The positive lever arm by the figure becomes 10.28 in. long and we have as before $\frac{10.28\,X}{2.57} = 4\,X$ = tension on the inner flange of spine from this source. The inward-acting transverse stress on the spine, obtained as in the previous instance, would be $\frac{9\,X}{3.5} \times 2 = 5.1\,X$, and the resulting secondary tension on the interior flange would be $\frac{2.55\,X + 3.5}{2.57} = 3.5\,X$, and the total tension on the flange $= 4\,X + 3.5\,X = 7.5\,X$. But the maximum tensile strength of the flange of 5-sq. in. area (assuming the unit stress at 17,000 lb. per sq. in.) = 85,000 lb., therefore $X = 11{,}300$ lb., which compares closely with the actual results of the tests for specimens Nos. 1, 2 and 3.

10 It would have added to the interest of the test, if the author had recorded the deflection of his specimens under various loads, for while the compresssion flange has little significance in offering resistance to rupture, yet it probably excercises an important influence in resisting deflection, a feature entirely ignored by Fairbairn and Hodgkinson when recommending their well-known type of beam, although this influence was previously recognized by Tredgold.

Prof. Walter Rautenstrauch. I was much surprised to find that Professor Jenkins' experiments with cast-iron frames of the C form had led him to the conclusion that the Andrews and Pearson formula gave results which were absurd when compared with those obtained by experiment. That the analysis should be so very incorrect when applied to cast iron was quite contrary to the opinion I had held after my experiments with hooks of wrought iron and cast steel, the results of which are reported in the American Machinist, October 7, 1909.

2 The table of breaking loads and maximum stress at breaking load, a quantity I have never been able to compute by any standard formula, was interesting but not at all adapted to throw any light on the subject of the relation between load and maximum intensity of

stress in cast-iron frames of this sort. In order that I might learn the true state of affairs at first hand, I had a few castings prepared similar to the one shown in Fig. 1 of Professor Jenkins' paper, and tested them. The results of these tests follow.

3 Four castings with dimensions as shown in Fig. 1 were prepared, two by the Isaac G. Johnson Company and two by another firm. The latter two were found to be very defective, being full of blow holes and imperfections which made the results of tests on them of no value. The C castings were tested in a Riehle 100,000-lb. testing machine, and the separation of the points A and B were read by a micrometer caliper to ten-thousandths of an inch. Loads and readings were taken, as shown in Table 1. Casting No. 1 broke as shown in Fig. 1. The relation between load and opening is shown in Fig. 2.

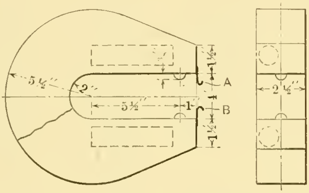


FIG. 1 DIMENSIONS OF TEST SPECIMENS

4 In tests on casting No. 2 (Table 2) the piece broke in the same manner as casting No. 1 and as shown in Fig. 1. Fig. 3 shows graphically the rate of opening with increase of load.

5 Tension-test specimens and compression-test specimens of standard form were cut from each casting, as shown by dotted lines in Fig. 1, and tested in an Emery hydraulic testing machine of 200,000-lb. capacity (Tables 4 and 5). The results are plotted in Fig. 4 and Fig. 5. The compression specimen from casting No. 1 was ruined and could not be used. The results of the tests on the specimen from casting No. 2 are shown in Table 3 and Fig. 5.

6 From the dimensions of the principal cross section of castings Nos. 1 and 2, as shown in Fig. 1, the functions γ_1 and γ_2 of the Andrews and Pearson formula were computed graphically and checked by analytical methods, giving $\gamma_1 = 1.126$, $\gamma_2 = 0.119$. The radius of curvature of the belly of the casting was found to be $r = 3.75$ in.

The distance from the point of application of the load to the center of gravity of the principal cross section was found to be $L = 9.3$ in.

TABLE 1 TESTS ON CASTING NO. 1

Load	Caliper Reading	Total Opening	Load	Caliper Reading	Total Opening
0	......	......	10500	0.3420	0.0799
500	0.2621	.....	11000	0.3468	0.0847
1000	0.2642	0.0021	11500	0.3515	0.0894
1500	0.2675	0.0054	12000	0.3567	0.0946
2000	0.2712	0.0091	12500	0.3617	0.0996
2500	0.2745	0.0124	13000	0.3702	0.1081
3000	0.2783	0.0162	13500	0.3738	0.1117
3500	0.2824	0.0203	14000	0.3772	0.1151
4010	0.2862	0.0241	14500	0.3822	0.1201
4500	0.2891	0.0270	15000	0.3878	0.1256
5000	0.2944	0.0323	15500	0.3942	0.1321
5500	0.2988	0.0367	16000	0.4000	0.1379
6000	0.3025	0.0404	16500	0.4050	0.1429
6500	0.3068	0.0447	17000	0.4102	0 1481
7000	0.3110	0.0489	17500	0.4172	0 1551
7500	0.3153	0.0532	18000	0.4228	0 1607
8000	0.3200	0.0579	18500	0.4298	0.1677
8500	0.3242	0.0621	19000	0.4354	0.1733
9010	0.3282	0.0661	19500	0.4432	0.1811
9500	0.3329	0.0708	20000	0.4493	0.1872
10000	0.3380	0.0759	20500	0.4569	0.1948
			21000	Broke	

TABLE 2 TESTS ON CASTING NO. 2

Load	Caliper Reading	Total Opening	Load	Caliper Reading	Total Opening
0	.....	.....	11070	0.3795	0.0844
500	0.2951	.....	12000	0.3885	0.0934
1080	0.2981	0.0030	13020	0.3992	0.1041
2040	0.3050	0.0099	14010	0.4079	0.1146
2930	0.3123	0.0172	14970	0.4207	0.1256
4030	0.3202	0.0251	15770	0.4300	0.1349
5050	0.3279	0.0328	16810	0.4417	0.1466
7040	0.3450	0.0499	18010	0.4548	0.1597
8030	0.3533	0.0582	18980	0.4677	0.1726
9000	0.3611	0.0660	20000	Broke	......
10030	0.3709	0.0758			

The distance from the center of gravity to the point most strained in tension was found to be $c = 1.8$ in. The area of the section was 9 sq. in. The moment of inertia of the section about the gravity axis was 9.72 biquad. in. The modulus of elasticity in compression was

TABLE 3 COMPRESSION TEST ON CASTING NO. 2

Diameter of Specimen = 1 in.

Actual Load	Load per sq. in.	Total Compres.	Actual Load	Load per sq. in.	Total Compres.
0	....	....	8000	10200	0.00120
500	637	0.00005	9000	11460	0.00140
1000	1273	0.00010	10000	12720	0.00160
1500	1910	0.00015	15000	19100	0.00280
2000	2550	0.00015	20000	25440	0.00380
2500	3180	0.00020	25000	31800	0.00510
3000	3820	0.00020	30000	38200	0.00690
3500	4460	0.00035	35000	44600	0.00900
4000	5100	0.00035	40000	51000	0.01200
5000	6360	0.00055	45000	57400	0.01500
6000	7650	0.00070	50000	63600	0.22000
7000	8900	0.00090	89800	114600	Failure

TABLE 4 TENSION TEST ON CASTING NO. 2

Diameter of Specimen = 0.503 in.

Actual Load	Load per sq. in.	Total Extension	Actual Load	Load per sq. in.	Total Extension
0	0	0.00000	3000	15000	0.00350
500	2500	0.00045	3500	17500	0.00450
1000	5000	0.00100	4000	20000	0.00570
1500	7500	0.00155	4500	22500	0.00720
2000	10000	0.00210	5000	25000	0.01130
2500	12500	0.00270			Failure

TABLE 5 TENSION TEST ON CASTING NO. 1

Diameter of Specimen = 0.506 in.

Actual Load	Load per sq. in.	Total Extension	Actual Load	Load per sq. in.	Total Extension
0	....	....	2500	12500	0.00225
500	2500	0.00030	3000	15000	0.00305
1500	5000	0.00060	3500	17500	0.00420
1500	7500	0.00095	4000	20000	
2000	10000	0.00165			

Grips slipped at 4000 lb. and the experiment was discontinued.

about 14,600,000 and the modulus of elasticity computed from the readings of the extensometer about 9,000,000 in the first case and about 6,000,000 in the second case.

7 The extensometer used, which was one devised by the officers in the materials testing laboratory of Columbia University, is considered more adaptable to measuring changes in the rate of stretch with load than the exact stretch at any particular load. This is especially true with short specimens such as were used in these tests. For this reason it is assumed that the modulus in compression and tension are approximately equal, although it cannot be proved by these tests.

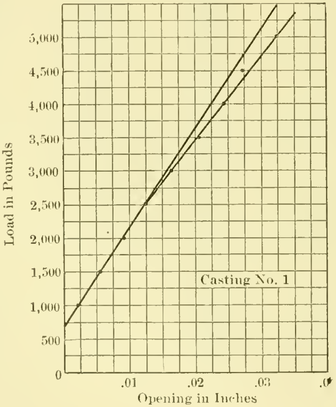


Fig. 2 Rate of Opening with Increase of Load

8 For frames of these proportions, on the basis that the stress in the material is proportional to the strain and that the modulus of elasticity in tension is identical with the modulus of elasticity in compression, and assuming $n = \frac{1}{4}$, the analysis of Andrews and Pearson results in the following formulation:

$$S = \frac{W}{A}\left[\frac{L}{r\gamma_2}\left\{\frac{1}{\left(-\frac{e}{r}\right)^{\frac{5}{4}}} - \gamma_1\right\} + 1\right]$$

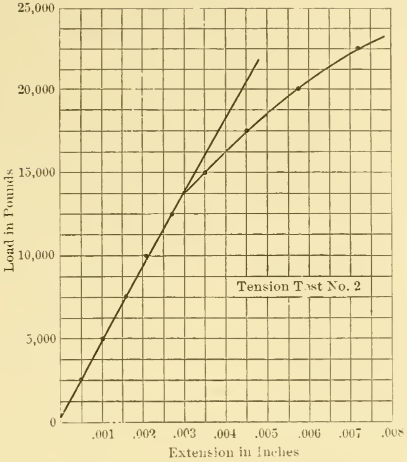


FIG. 4 STRESS-STRAIN DIAGRAM

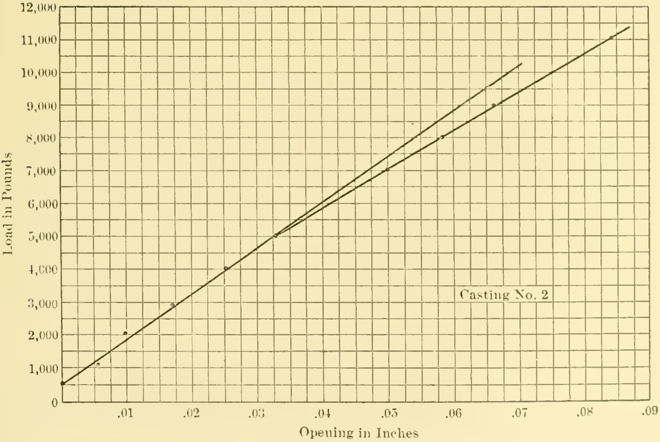
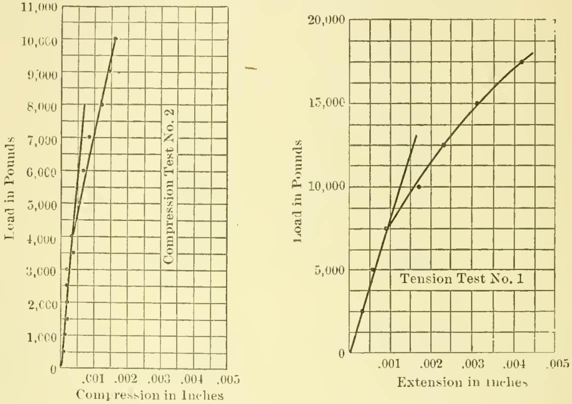


FIG. 3 RATE OF OPENING WITH INCREASE OF LOAD

where the notation is the same as that employed by Professor Jenkins. Substituting the values applicable to these castings, it is found that

$$S = 2.035\, W$$

Upon inspection of Fig. 2 it will be noted that casting No. 1 begins to change its rate of opening at some load between 2500 and 2750 lb. and accordingly the rate of stretch with load on the tensile test specimen is predicted to change at a load between 7100 lb. and 7800 lb. per sq. in. Reference to Fig. 6 will show that the change in the rate of stretch with load when the specimen was tested in tension took place at 7500 lb. per sq. in. Casting No. 2 begins to change at about 14,150 lb. per sq. in. Referring to Fig. 5 it is seen that the change in the rate of stretch in the specimen when tested in tension takes place at about 13,750 lb. per sq. in.



Figs. 5 and 6 Stress-Strain Diagrams

9 According to the formula usually applied to such cases the following results would be expected

$$S = \frac{Mc}{I} + \frac{W}{A}$$

in which the symbols are as used by Professor Jenkins. For the particular dimensions of these castings the formula may be written

$$S = 1.834\, W$$

For casting No. 1 this formula would indicate that for a tensile stress of 7500 lb. per sq. in. a load of 4100 lb. would be required, while for casting No. 2 in order that the tensile stress reach 13,750 lb. a load of 7500 lb. would be required. A comparison of the results of these analyses wtih the experimental results is sufficient proof of the accuracy of the Andrews and Pearson formula.

10 In criticism of Professor Jenkins' paper it is noted that the statement made in Par. 13 that the results of the stress predicted by the Andrews and Pearson formula is absurd, is unjust and misleading. The formula is not intended to be used to compute stresses up to the breaking point of the material and such an application of the formula is proof of nothing. That Professor Jenkins found the rate of opening of the frames with load practically constant as stated in Par. 29 is evidence of the fact that the method employed in determining the openings at different loads was not sufficiently refined. In conducting experiments of this sort great accuracy and refinement must be used with either wrought-iron and cast-iron specimens or no results need be expected.

11 In regard to the statement made in Par. 5 relating to the value of Poisson's ratio, it will be found that a change in this ratio from 0.25 to 0.30 will not affect the result more than 3 per cent.

12 Because of the results of these few experiments and in view of the fact that Professor Jenkins' method of experimentation and analysis was not adapted to proving any theory of stress-strain relations, it is believed that the case against the Andrews and Pearson formula is not proved.

13 In conclusion, attention is called to the fact that the uncertain nature of cast iron and the impossibility of determining the effect of shrinkage stresses and imperfections in the casting involve a considerable element of doubt as to the proper working stress to be allowed, no matter what analysis of stress-strain relations is used. But these uncertainties do not justify the application of inaccurate formulae for the determination of the relation between load and maximum intensity of stress. In fact a more accurate analysis of the case as seems to be given by the Andrews and Pearson formula tends to lessen the elements of uncertainty.

Frank I. Ellis. I have always felt, as have my associates who have had considerable experience on this line of work, that the relation of the ultimate strength of a curved cast-iron specimen to that of an attached test bar is a very difficult one to determine. We do not think anything can be gained by making sample curved sections such as carried out by the author of the paper, unless they are made full size. We have found that in comparing different-sized machines, for instance, one with a housing weighing approximately 9000 lb. against one with a housing weighing 40,000 lb., the relative values as compared with a test bar are not at all the same. We have made no special tests for several years, but carry out all our designing very much on the lines of the conclusion Professor Jenkins came to, that is, design the member from the formula given in those conclusions and then correct to suit our experience. In other words, we figure as closely as possible and then make a further allowance. We commonly use 2500 lb. and sometimes 2000 lb. per sq. in. as a safe value for cast iron for the tension side of all shear housings. On other work we run up in some cases as high as 4500 lb., but in such machines as vertical shears, we would not think of using anything higher than 2500 lb.

2 The paper is a very interesting one, but it has not brought out any new facts in relation to this subject.

Henry Hess. The real question at issue is not one of formulae at all. What should be considered is the yield point; in other words, the elastic limit. The real trouble is that the elastic limit of the material is seldom accurately known. There is now in existence a testing apparatus, probably not familiar to many, which makes it possible to recognize the absolute elastic limit of any structure in any material. This instrument is based on a law which is fairly well recognized, but only recently embodied in practical instruments. This law states that deformation is accompanied by a rise in temperature and that such rise is very marked at the point of change of proportionality between stress and deformation. The instrument consists of a delicate pyrometer and a sensitive gold-leaf galvanometer and shows a sharp break in the recorded line when the elastic limit is reached. If the line starts at an inclination of 45 deg. the change in direction at the elastic limit is not gradual, but is an absolutely definite break to an inclination of say 30 deg. This eliminates all doubt as to the exact value of the elastic limit. The small pyrometer may be clamped in any convenient way to any portion of such structure.

2 The ordinary formulae will apply when there is substituted for the element of inaccuracy, the value of the material constant, absolutely definite knowledge of its value.

Oberlin Smith. In Fig. 1 herewith, which represents the outlines of a typical C-shaped beam such as is used in many forms of press frames, AA is the ram axis along which the pressure acts to force the ends of the beam apart and NN is the neutral axis. My usual practice has been to make the depth of the beam at DD, $D'D'$, and $D''D''$ such as to give equal strength on the line AA when calculated by the cantilever beam formula, with LL and $L'L'$ and $L''L''$ as the respective beam lengths. The breadth of these sub-beams, as they might be called, if uniform would be represented by BB in Fig. 2 or Fig. 3 and the formula would of course depend upon the shape of the cross section. If I am in error in this treatment of the subject I should be very glad to hear from others who have made a closer study of the matter.

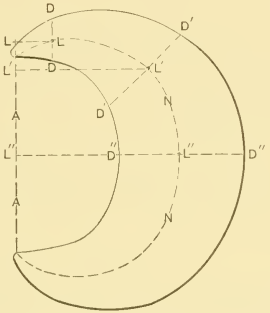
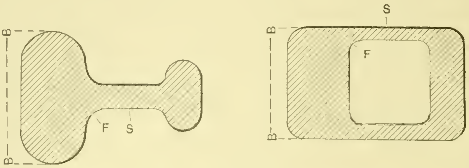


Fig. 1 Typical C-Shaped Beam

2 There is a tendency in a beam of this kind for the web to split longitudinally, approximately on the neutral line, due to the tensile stress mentioned in connection with section AG of Fig. 8 of the paper. The writer has had webs of presses split at S in Figs. 2 and 3 and somewhere along NN in Fig. 1.

3 There are many cross-sections for press frames, but the most usual are shown in Figs. 2 and 3. These are equally good as regard resisting vertical stresses on the line AA (Fig. 1). In regard to torsional and lateral bending stresses, Fig. 3 has much the advantage. Presses are frequently subjected to other than the normal vertical stresses on account of large dies striking the work irregularly, perhaps

on one corner at a time, thus having a tendency to bend and twist the frame of the machine. Obviously, no better shape than Fig. 3 could be contrived for all these stresses and, furthermore, such a form of machine is much more beautiful, as well as more solid and rugged in appearance. The form shown in Fig. 2, however, is in more general use, doubtless because it is cheaper to make, both as regards pattern-making and molding.



Figs. 2 and 3 Common Forms of Press Frames

4 In any case, the fillets shown at *F* (Figs. 2 and 3) should be made very large to avoid cracking in cooling as is very likely to happen on account of the massive tensile member joining the much lighter web.

Wilfred Lewis. Thirty years ago punch and shear frames were made with a section as shown on the left of Fig. 1 herewith and they always split at *AB*. I came to the conclusion that the weakness in all such frames was in the web and I changed the form to that on the right of Fig. 1. I have never heard of a broken frame of this section.

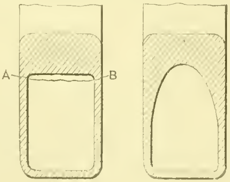


Fig. 1 Sections of Punch and Shear Frames

2 There is no mystery about the breakage at AB, for if tension or compression is running in a given direction it cannot be deflected without putting a strain on the web, which must be strong enough to deflect these forces around the curve. The reason why curved beams do not develop their estimated strength is in my opinion simply due to the fact that no attention is paid to the section of web necessary to deflect the tensile stress in the flange.

John S. Myers.[1] .A careful consideration of the paper by Professor Jenkins seems to indicate five things:

a That for solid sections of cast iron, such as specimens Nos. 1, 2 and 3, the common beam formula comes much nearer to an expression of the facts than does either that of Résal or of Pearson and Andrews.

b That such specimens fail at a stress approximately 86 per cent of the ultimate tensile strength of the test specimen when computed by the common beam formula, which may be due to any one of a number of causes, such as un proportionality of stress to strain beyond the elastic limit, shifting of the neutral axis due to inequality of the coefficients of elasticity for compression and tension, the curved form of the specimen, or deformation due to shear parallel to the neutral plane.

c That the limited number of the tests on solid sections and the small size of the specimens used still leaves room for considerable uncertainty as to the behavior of larger castings.

d That the safest course for designers to pursue until more light has been shed upon the subject is to continue as heretofore, that is, to use the common Unwin formula but to keep the working stress between 1500 and 2000 lb. per sq. in., thus insuring rigidity, and pay no attention to the probable ultimate sustaining capacity.

e Finally, that the matter really seems of little practical importance if confined wholly to solid sections of cast iron, as such sections are notoriously uneconomic and hence seldom used.

2 In the matter of the I-sections experimented upon, the peculiar manner in which failure occurred was to be anticipated, for, while the design of the specimen chosen is quite a common type, it is none

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[1] 2456 Almond St., Philadelphia, Pa.

the less an improper and entirely illogical construction, as was pointed out by the writer in an article appearing in the June issue of Machinery, from which the following extract is made: "The application of a little common sense should make it apparent that if we have a flange in tension or compression we must not suddenly give it a 90-deg. or 180-deg. bend and expect the stress in that flange to go shooting around the corner like a cable car, but we must *provide means for the distribution of that stress* and carry it where it may meet an equal and opposite load to balance it; for no stress induced by flexure springs suddenly into existence or dies out suddenly; it is gradually built up and gradually dies out again;" so instead of trying to deflect nature from her course we should humor her.

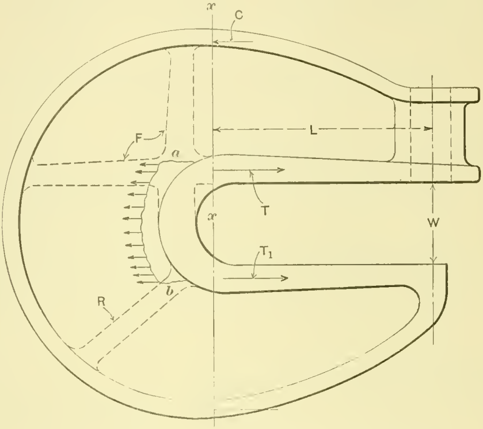


Fig. 1 Bull Riveter Frame of Usual Design

3 "As an example of improper construction, take the bull riveter frame shown in Fig. 1. Here it is quite obvious that if the web were to part along the line *ab* there would be nothing to balance the loads T and T_1 in the tension flanges, and failure to balance these forces would mean failure for the entire frame. The total flange loads are, approximately,

$$T \doteq \frac{WL}{h} \quad \text{and} \quad T_1 \doteq \frac{WL}{h_1},$$

and if w = thickness of web, the average unit tension distributed over the web along line *ab*

$$t = \frac{2\,WL}{hw\ (ab)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

or, if h_1 does not equal h,

$$t \doteq \frac{T + T_1}{w\ (ab)} = \frac{WL}{w\ (ab)}\left(\frac{1}{h} + \frac{1}{h_1}\right) \quad \ldots\ldots\ldots\ldots\ldots [2]$$

4 "From this it would appear that the sectional area of the web along line *ab* should be approximately equal to the combined area of the *two* tension flanges, and were it not for the fact that it is necessary to thicken up the web at this point in order to avoid shrinkage cracks, there would probably be more frequent failures due to this improper construction."

5 That this point just back of the flange is the weakest place in the frame has been fully demonstrated by the tests conducted by Professor Jenkins and it seems that the obvious thing is to correct the construction by adding a diagonal rib as indicated by the dotted lines at *R* or else by continuing the flanges as at *F* (Fig. 1). The latter would permit the stress in the flanges to die out gradually in a natural mannner and from a theoretical viewpoint would be the more logical method. The method of the single diagonal rib is an attempt to deflect the stress generated in the vertical flanges "around the corner" by the application of a resultant force in the rib, which reinforces the web at this critical point. This method is probably more economical of material than the former one. To omit all such ribs and permit the full flange load to concentrate upon the web is clearly an improper distribution of material and the existence of many such designs is no doubt due to a misconception of fundamental principles.

6 It would seem that most students are taught that any stress due to bending is entirely dependent upon the bending moment at the section and that the only necessary requisite is that the internal forces must balance the external ones. Thus we find designers who pay absolutely no attention to the manner in which these internal forces are built up by the transference of the vertical shear from section to section. Now the method I have proposed in connection with equation 2 is open to the objection that it is not very exact,

owing to the somewhat indefinite nature of the distance *ab*, but it at least has the justification of recognizing the real cause of the weakness.

7 The absurd results given by the Pearson-Andrews formula are not surprising because the principal quantity in this analysis is the radius of curvature of the gravity axis P_o of successive sections and this quantity has absolutely no mathematical relation to the flange curvature, as is clearly shown by Fig. 2. Here the rear flange of a C-frame is shown concave and of such a curvature as to make the gravity axis curve *ABCDE* a straight line at point *C*, in consequence of which $P_o = \infty$, while *OF* = the flange curvature.

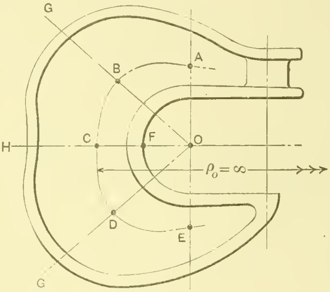


Fig. 2 Riveter Frame Designed by the Application of the Pearson-Andrews Formula

8 This is, of course, an abnormal construction, but while improbable is not at all impossible; in fact the compression flange is often considerably less in area at point *H* than at point *G*, which has an effect upon the curvature of the gravity axis similar to a reverse curve in the rear flange, although not so readily seen. For such a case the Pearson-Andrews formula reduces to the same value as the usually applied Unwin formula, yet it is clear that there is just as rapid transition of stresses around the throat as there would be were the value of P_o equal to *OC*.

9 I would like to present a problem for solution which should have some bearing on the subject under consideration but more strictly a problem relating to flexure in general than to the specific case of curved machine elements. As is well known, the common theory of

flexure assumes that any section being plane before flexure remains so after flexure; hence, stress varying as strain, the stress varies directly as the distance from the neutral plane. Now stresses due to flexure are induced by the transference of vertical shear from some point on the member to some other point and flexural stresses are thus built-up stresses, i.e., they result from a process of growth. So long as the flexural stress is receiving an augment there exists a shear on the neutral plane and all planes parallel to it and since any stress, be it tension, compression or shear, must of necessity produce a corresponding strain, this horizontal shear must be accompanied by a sliding upon each other of the so-called fibres. The common theory of flexure recognizes no such deformation, hence it must assume that the coefficient of elasticity for shear is infinite when compared to the coefficient of elasticity for tension or compression. As this is entirely at variance with fact it should be expected that this horizontal shear would have an important effect upon the distribution of the stresses, especially for sections with heavy flanges and comparatively light webs, subjected to a heavy vertical shear, such as the frames of punching and riveting machinery. Briefly, the problem is this: Deduce an equation which shall express the manner in which the stress varies over the cross-section of box and I-sections when taking into account the deformation due to horizontal shear.

S. A. Moss. It occurs to me that the failure of some of the specimens at the junction of flange and web might be due to insufficient fillet, which nullifies any mathematical analysis.

2 I had always supposed that the three types of formulae mentioned were practically equivalent, and differed only so far as minor corrections were concerned. The results seem to show that there is a fundamental difference, however. What is the mathematical reason for this and what mathematical points are taken account of in one formula and not in the others? As I understand the matter, the best that the designer can do is to use formulae 6 and 8 of the Appendix. What values of the experimental constant K does Professor Jenkins recommend?

3 The paper shows how exceedingly weak our mathematical engineering is. There appear to be three points of uncertainty, the fundamental criterion for a safe stress, the law of distribution of stress in a beam, and the mathematical solution of the bent beam problem. It seems to me that a good fundamental criterion is permanent set, and that a part ceases to be useful when the permanent

set reaches some predetermined appreciable amount. According to this criterion, the stress which gives such appreciable set must be known, and the working stress must be a safe fraction of it. In other words, the stress where appreciable permanent set begins could be substituted for breaking stress. This criterion would require that in tests such as those of the present paper, the permanent set at various loads be found from the autographic record by removing most of the load at frequent intervals. The mathematical formulae may apply up to the limit of appreciable permanent set even though they do not apply up to the breaking load.

4 The elastic limit, yield point, or bend in the stress-strain curve, often used as a criterion for safe stresses, may or may not correspond to stress at which appreciable permanent set begins. It is merely a matter of interest, and not particularly important if there is such coincidence, since we can directly use as our criterion the stress at which appreciable permanent set begins.

5 A complication which would have to be taken account of in using this criterion on some materials, such as brass and bronze, is the fact that the first application of a load causing permanent set changes the material, so that it will better stand succeeding loads. In such a case the criterion might be the stress whose second application gives an appreciable permanent set. In the mathematical analysis of the simple or bent beam, it is probable that the application of the maximum shear theory will be of value. This theory was proposed by Guest and Mohr some years ago and has recently been discussed by other writers. It seems probable that this theory will be the basis of all treatment of stresses other than uniform tension and compression in the future.

6 This theory states that the phenomenon in which an engineer is interested is not tearing apart as in tension but sliding apart as in shear, and that the maximum shearing stress at each point is the matter which must be investigated. In other words, the way in which metals fail is by shear, and not by tension or compression considered strictly as such.

7 It seems to me that the combination of these two points, giving as a criterion the shearing stress at which appreciable permanent set begins, would give a rational solution of the present problem.

George Westinghouse stated that it was his belief that most engineers pay too little attention to the time element in castings. Machine members are tested or put into service without giving the molecules time to adjust themselves so as to relieve the casting strains. Automobile cylinders which are annealed between the rough and finish turnings are more reliable than untreated castings.

E. J. Loring. The greater ease of calculating sections by the ordinary beam formula would make of considerable value any simple means of correcting its results for curvature of the beam. Professor Jenkins appears to infer that the manner of distribution of stress in cast iron acts to supply such a correction, which would be exceedingly important if true.

2 It would seem extremely improbable that such a result, if true for one set of conditions of curvature, depth of gap, etc., would be true for other proportions.

3 Examining the tests, specimens Nos. 1, 2, 3, 10, 11, 14, 15, 16, 18 unquestionably failed at the section under consideration. Of these we have

		per cent
No. 10, T-section (flange out)	$\frac{\text{Unit stress by beam formula}}{\text{Unit stress, tension specimen}}$	= 51
No. 11, I-section (flange out)	“	= 77.9
No. 1, plain section “	“	= 85
No. 2, “ “	“	= 86.5
No. 3, “ “	“	= 87
No. 16, “ “	“	= 76.4
No. 18, “ “ (necked)	“	= 94
No. 14, T-Section (flanged in)	“	=109.7
No. 15, “ “	“	=109.3

so that, according to the shape, the results by the beam formula may be 10 per cent greater or 50 per cent less than the tensile test strength of the material, which can hardly be considered a close agreement.

4 The condition of stress on the section lies between the conditions of tension and transverse tests, and if the results by these two methods of test are averaged we would have a very rough approximation to the unit stress under the actual conditions. Where the values of the unit stress by the Résal and Pearson-Andrews formulae are given for the above mentioned specimens, it will be found that in every case but Nos. 14 and 15, (T-section with flange in), the average thus taken lies between the values given by these formulae, apparently indicating that these give a closer approximation to the

actual stress. In Tests 14 and 15 the average is greater than by either formula.

5 I fully agree with conclusion *e*, particularly as to the chances of error in the use of these formulae, but I distinctly disagree with conclusions *b* and *d*.

The Author. Mr. Christie infers that failure behind the flange of C-shaped castings is due to sudden change in cross section and refers to Professor Marburg's tests on steel I-beams which failed by lateral deflection of top flange and by twist of web, manners of failure not observed in C-shaped specimens of cast iron and not applicable to his statements. The method of analysis suggested by Mr. Christie has hardly enough rational bearing to commend its use, although it seems to fit this particular case very well.

2 There is no reason for believing the internal stresses due to cooling were sufficient to affect the results, for reasons given in Par. 15*a*. The age of the castings varied from two to six weeks.

3 In Professor Rautenstrauch's tests of castings, referred to in his discussion, deflection readings were taken, which, when accurately plotted and a curve drawn through the points, show no sudden change in the proportionality between load and jaw opening; but in order to locate this point for comparison he uses two straight lines instead of a curve, and since it is possible to draw an infinite number of tangents and chords to a curve he is able to get intersections anywhere he desires.

4 The lines he gives are in contradiction of such authorities on the elastic properties of cast iron as Kupffer,[1] Love,[1] Saint Venant,[1] and Professor Pearson,[1] as well as any well known authors on the strength of materials. Professor Pearson, who is responsible for the formula in question and should be satisfactory authority on this subject, states on p. 733 that "Hooke's law does not hold for cast iron even in the case of very small strains." Professor Morley states that the elastic limit of cast iron is at almost zero.

5 The I-beam shown in Fig. 1 was cast from the same heat as the curved specimens and was used in studying the resistance to horizontal shear. This specimen was tested as indicated in Fig. 1 and the autographic record is presented in Fig. 2, which in no way suggests a sudden change in the rate of deflection similiar to that shown in Professor Rautenstrauch's diagrams.

[1] History of Elasticity, by Todhunter and Pearson, Vol. 2, Pt. 1.

6 The elastic laws for cast iron are given in Par. 1 and Par. 2 of the Appendix and when plotted show no point that will permit the use of Professor Rautenstrauch's method of analysis.

7 The sudden change in the rate of stretch of his test bars is easily accounted for by the fact that they were stressed to that point in testing the casting, it being known that an artificial elastic limit can be given cast iron by previous loading.[1]

8 The curves shown in Fig. 3 were drawn by the autographic recorder and are undoubtedly more accurate than those given by Professor Rautenstrauch. They show no elastic limit or yield point, as stated in Par. 29.

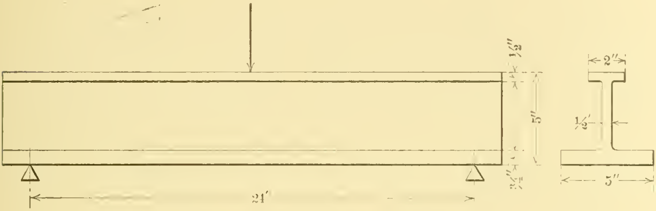


Fig. 1 I-Beam used for Studying Resistance to Horizontal Shear

9 His criticism of Par. 13 is that it is unjust and misleading. It is admitted that the Pearson-Andrews formula is not true for breaking load and as the object of these experiments, as stated in Par. 2, was to determine the strength of the castings, it is not easy to see how the formula can give other than absurd results for this condition. In The Journal for February he stated that "the formula has not as yet been sufficiently well developed to determine its usefulness in establishing proportions for sections other than those at right angles to the load." According to this statement the formula does not apply to his tests on cast-iron specimens because they did not fail at right angles to the load.

10 It occurred to the author to use Professor Rautenstrauch's method of analysis, but investigation showed that it is not applicable to cast iron and has the following objections when used for steel:

[1] Trans. A.S.M.E., Vol. 17, p. 694.

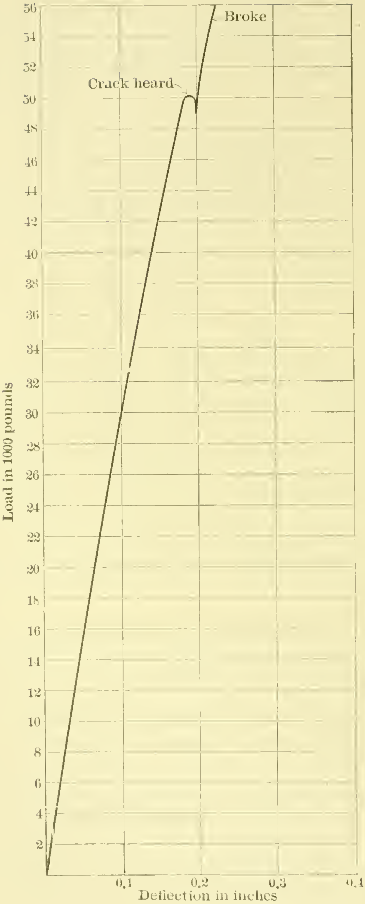


FIG. 2 FULL-SIZE AUTOGRAPHIC RECORD OF BEAM IN FIG. 1

a The formula only applies to specimens with curved spines.

b It is only true for one section of the specimen.

c The load-deflection curve gives the total deflection or the deflections of an infinite number of sections.

d The specimen may yield first at a section some distance from the one assumed by this method without detection.

e It is possible for a casting to yield in the straight portion similar to a straight cantilever beam while the calculation is made for a section in the bent portion, which would be quite erroneous.

11 From a theoretical standpoint there is no doubt about the accuracy of the Pearson-Andrews formula for stresses within the elastic limit of materials that obey Hooke's law; but it is not true for cast iron, even for the smallest loads. If someone should substitute the exponential or parabolic laws for Hooke's law in the formula he would have reasons for his plea of defense when the formula is placed on trial.

12 It appears to the author that Professor Rautenstrauch's calculations based on the sudden change in the rate of stretch for cast iron, the existence of which is denied by the best authorities, and a formula based on an elastic law that is not true for cast iron, cannot be taken seriously. They were, moreover, applied to two test specimens only.

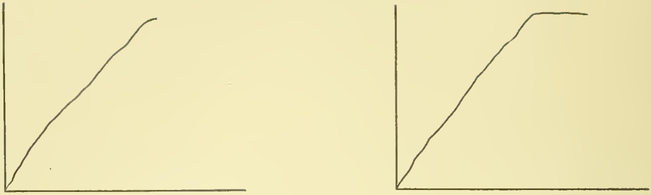
13 The author infers that Mr. Hess, in his discussion, proposes that we should make a critical study of the elastic properties of cast iron and modify our formulae to suit the actual conditions, which is a point well worth considering.

14 The testing apparatus he mentions is probably that described by Mr. E. Rasch in a paper before the Copenhagen meeting of the International Association for Testing Materials. The use of this method involves the coefficients of heat conductivity and radiation.

15 The method of analysis suggested by Mr. Myers is less accurate and has the same objections as the similar method given in Par. 15*b* of the paper. A much more logical method and one that recognizes the real cause of the weakness is given in Par. 15*c*.

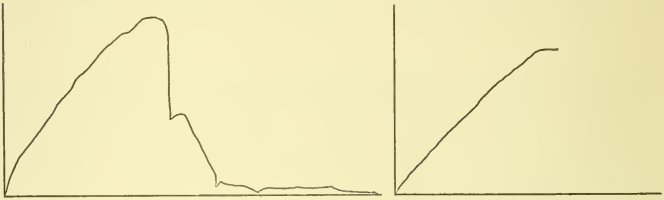
16 His method of permitting the stress in the flange to die out gradually and not go shooting around the corner like a cable car by adding a diagonal rib is certainly insufficient because the casting fails along *ab*, which is between the proposed ribs. This may be done by increasing the thickness of the web where the weakness exists.

17 Mr. Myers states that stresses due to flexure are induced by transference of vertical shear from some point in the member to some other point and asks that an equation be deduced to express the manner in which stress varies over the cross section of box and I-sections when taking into account the deformation due to horizontal shear.



Specimen No. 1

Specimen No. 2



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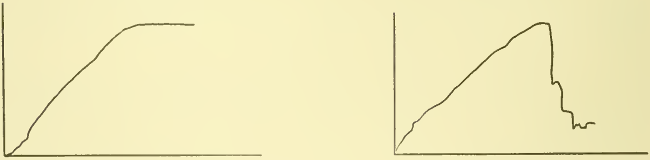
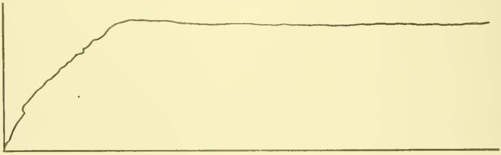
Specimen No. 4



Specimen No. 5

Specimen No. 9



Specimen No. 10

Fig. 3 Autographic Stress-Strain Curves

18 Fig. 4 shows the forces acting on a very small rectangle at the point A in Fig. 5. The normal forces tt are due to bending, whereas the forces s_v s_v are due to vertical shear. Now it is easily seen that these two sets of forces wanted cause the rectangle to rotate and it is necessary to introduce the forces s_h s_h to effect equilibrium. Hence, the horizontal shearing forces s_h s_h must always equal the vertical forces s_v s_v.

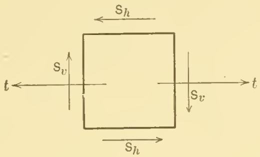


FIG. 4 FORCES ACTING AT A (FIG. 5)

19 The total vertical shear on the section x distance from the support, in Fig. 5, is

$$Q = \frac{d\,M}{d\,x}$$

which is the rate of change of the bending movement and is analogous to acceleration. The intensity of shear at any point in the section may be expressed by the equation

$$q = \frac{Q}{I\,z} \int_{y}^{y'} z\,y\,dy$$

where

q = unit shearing stress at y distance from the neutral axis
Q = total shear on section
z = breadth of section at y distance from neutral axis
I = moment of inertia

The normal stress at any point in the section is determined by the formula

$$S = \frac{My}{I}$$

20 An idea of how the apparent stresses S and q, are distributed over various sections of a rectangular beam may be gained from the diagrams given in Fig. 6.

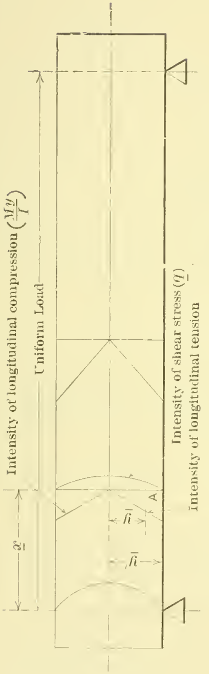

Intensity of longitudinal compression $\left(\frac{My}{I}\right)$
Uniform Load
x
Intensity of shear stress (q)
Intensity of longitudinal tension
A
$\bar{h}$
$\bar{h}$

FIG. 5 DISTRIBUTION OF STRESSES IN RECTANGULAR BEAMS

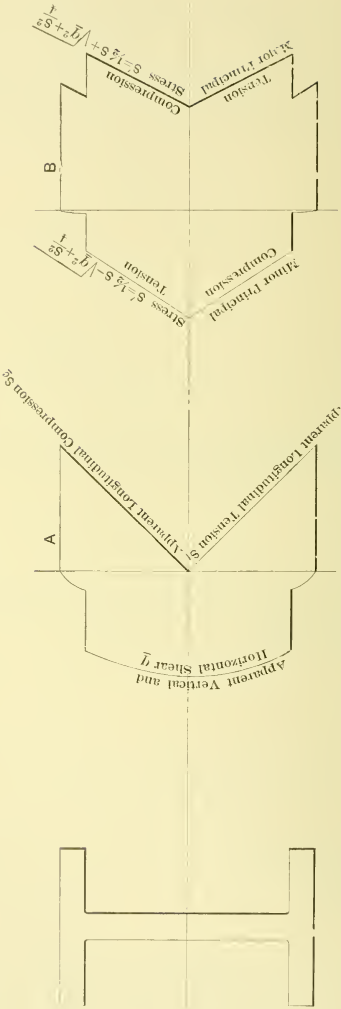

B
Compression
Stress $S = \frac{1}{2}S + \sqrt{q^2 + \frac{S^2}{4}}$
Tension
Major Principal
Stress $S = \frac{1}{2}S - \sqrt{q^2 + \frac{S^2}{4}}$
Tension
Compression
Minor Principal
Apparent Longitudinal Compression S
Apparent Longitudinal Tension S
A
Apparent Vertical and Horizontal Shear q

FIG. 6 DISTRIBUTION OF STRESSES IN I-BEAMS

21 The maximum resulting shear at any point due to the stresses S and q is

$$q' = \sqrt{q^2 + \frac{S^2}{4}}$$

and makes an angle Θ with the neutral surface such that

$$\tan 2\,\Theta = \frac{S}{2q}$$

22 The principal unit stress at any point is

$$S' = \tfrac{1}{2} S \pm \sqrt{q^2 + \frac{S^2}{4}}$$

and makes an angle ϕ with the neutral surface such that

$$\tan 2\,\phi = -\frac{S}{2q}$$

23 The equivalent normal stress, namely, a linear stress that would produce a deformation equal to that actually produced by S and q is

$$S = \frac{(1-\lambda)}{2} + \frac{(1+\lambda)}{2}\sqrt{4q^2 + S^2}$$

where λ is Poisson's ratio.

24 Fig. 6 shows how the apparent and principal stresses are distributed over a section of an I-beam, diagram *A* showing the variation of the apparent stresses S and q and diagram B the variation of the principal stresses S', the direction of which may be found at any point by determining the value of ϕ. Diagram B shows how the stress at the juncture of the flange may be greater than the stress at the outer fibre. The value of q' may also be sufficient to produce failure.

25 The step in the curve shown in Fig. 2 is due to internal failure caused by the principal stress.

26 The above discussion is only applicable to straight beams and does not pertain to the spine of a curved beam because of the absence of shear in that portion. This fact may be seen from the inspection of Fig. 7, which represents a *C*-frame consisting of a solid block *C* connecting the two straight beams *A* and *B*, which consist of two pieces riveted together. The beams are subjected to vertical and horizontal shear, and there exists a tendency to shear the rivets in them, but the piece *C*, although it may bend, is free from shear.

27 Dr. Moss wishes to know what mathematical points are taken into account in one formula and not in the other. They differ essentially as follows:

a The beam or Unwin formula merely considers the stress due to bending and the direct pull of the load and is based on the same assumptions as the fundamental formula for straight beams.

b The Résal formula takes into consideration the stress due to bending and the effect of curvature.

c The Pearson-Andrews formula considers the stresses due to bending and direct tension, the curvature and lateral contraction.

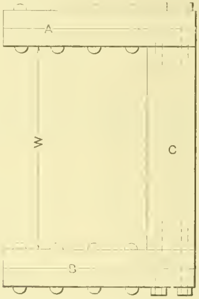


Fig. 7 C-Frame Showing Absence of Shear in C

28 They are all based on Hooke's law and Bernoulli's assumption, neither of which are true for cast iron. The assumption that these are true has been the source of weakness in all rational formulae for cast-iron beams, and all attempts to improve the formulae by basing them on the actual laws governing the properties have been futile owing to the mathematical complications involved.

29 Formulae 6 and 7 of the appendix are for castings having straight spines of rectangular cross-section. The value of K depends on the size of the casting, temperature of power, rate of cooling, and percentages of silicon and carbon. For the specimens tested it has a value of about 7.3.

30 Dr. Moss states that the stress where appreciable permanent set begins could be substituted for breaking stress. Professor Morely

states in his Strength of Materials that slight permanent sets may be detected under very low stresses. As evidence that the permanent set at the breaking point is not very pronounced, Lynde[1] made experiments on 89 girders of 30 ft. 9 in. span, one of which he tested to rupture, and remarked that no permanent set was visible. In view of these statements such procedure would not be practical.

31 Guests' maximum shear theory is only applicable to ductile materials and does not apply to cast iron. The proof of this fact is brought out in an article by the author in Engineering (London), November 12, 1909.

32 The point raised by Mr. Loring in regard to the distribution of stress making corrections for curvature when the beam formula is used, is explained in Pars. 29 and 30 of the Appendix. The distribution of stress tends to make such a correction, but the amount depends upon the proportions of the section and the elastic properties of the material and may be determined by formula 2 and the results obtained by the method described in Par. 6 of the Appendix.

33 In tabulating the percentages of disagreement between the strength of the test bar and the results given by the bean formula, he omitted No. 17 and introduced No. 10, which, as stated in Par. 19, had a flaw in the section that failed. Omitting No. 10, the values vary from 10 per cent greater to 23 per cent less, which is closer agreement than the 44 per cent given by the Résal and 73 per cent by the Pearson-Andrews formula

34 He also suggests averaging the tensile and transverse strengths of the specimens and comparing the results with averages made between the values given by the Résal and Pearson -Andrews formulae. Because such a comparison gives closer agreement than the above, he concludes that conclusion *b* is not justifiable. This unique method of comparing results has no rational significance and is not sufficiently well grounded to disprove conclusions *b* and *d*.

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[1] History of Elasticity, Vol. 2, Pt. 1, p. 866.

GAS ENGINES FOR DRIVING ALTERNATING-CURRENT GENERATORS

By H. G. Reist, Published in The Journal for June 1910

ABSTRACT OF PAPER

This paper points out briefly the problems that must be solved to obtain the best parallel operation of alternating-current generators when driven by means of gas engines. While some assistance can be given when designing the generator, the most satisfactory solution of the problem is so to design the gas engine that even rotation is obtained as nearly as possible. This should be done without the use of a very heavy flywheel.

DISCUSSION

P. M. Lincoln. I am obliged to take issue with Mr. Reist on one of the most important conclusions in his paper, that contained in Par. 6, in which he states that "if there were no inertia, the rotating parts of generator and flywheel would quickly get into synchronism, reducing and almost eliminating the cross-currents." The truth of this statement depends entirely upon the definition of cross-currents. It is usually understood that if the flow of energy from all of the alternating-current units in parallel is not essentially the same at all times there are said to be cross-currents. If this definition is accepted, Mr. Reist's statement is entirely unfounded. It is obvious that the flow of energy from a gas engine or any reciprocating engine is not uniform. There are some instances when it is a maximum, others when it is a minimum and in some cases it is even a minus quantity, as for instance when compression is taking place. If there were no inertia in the gas engine the flow of energy from the alternator into the circuit would be just as uneven and differ just as much from the uniform flow as the generation of this power within the cylinders. The fact that a gas-engine-alternator combination possesses inertia introduces another element into the energy flow equation. With inertia the rate that energy flows into the circuit is equal to its rate of generation minus its rate of storage in the reciprocating and rotating parts. By designing these parts properly the flow of energy into the circuit can be made much more uniform than its rate of generation. If gas engines and their generators could be built without inertia the condition that would then obtain would be far from ideal, as Mr. Reist states. In fact, the phenomenon which we know as cross-currents would be much larger if inertia were entirely absent than in the ordinary cases with which we have to deal.

2 Mr. Reist also makes the following statement with which I cannot agree: "If the flywheel is very large the currents which it may be practical to allow to flow between the machines may not be able to draw them together at all." While this may be true as an isolated statement, it has no bearing upon the problem in hand. With very large flywheels there would be no occasion for large currents to flow between the various units in parallel. In general, the larger the flywheel the more uniform will be the rotation and therefore the more uniform the flow of energy from that combination as compared with its rate of generation. Hence what we know as cross-currents will be reduced to a minimum.

3 There is one very important element in parallel operation of alternators which Mr. Reist neglected to mention. If any generator is displaced from its normal position in its magnetic field, a force equivalent to a spring at once acts to return it to the normal position. The greater the departure from normal position the greater will be the force acting to return it. Any mass which contains such an element has a natural period of vibration. In the combination of alternator and engine the natural period of vibration will depend upon the inertia of the moving parts and the electrical and magnetic characteristics of the generator. If the impulses imparted to this mass by the engine are in resonance with the natural period of vibration, a state of affairs will exist which makes it very difficult and sometimes impossible to operate alternators in parallel. It is exceedingly important, therefore, in designing gas engines and the connected alternators to make sure that the natural period of vibration of the rotating parts of the combination is not in resonance with the impulses which may be imparted by the gas engine.

4 Another thing which Mr. Reist neglects to mention is the possibility of missing engine power strokes. It is usual to design flywheels on gas engines so that the departure from uniform rotation will not be excessive even when a power stroke of the gas engine is missed. It is evident that if the flywheels are made large enough to take care of

this contingency there will be more than ample capacity when the explosions are taking place uniformly. So long as normal conditions obtain, that is uniform explosion, the normal operation of gas engines in parallel is usually better than that of steam engines in parallel.

THE AUTHOR. Mr. Lincoln's criticism regarding cross-currents on generators is apparently a matter of definition. Cross-currents flow between generators from a number of causes, such, for instance, as the difference in wave shape of the several machines, or differences in excitation and currents flowing between the generators due to the generators being out of phase. The first two are so-called wattless currents and the last is energy current. This is the class of cross-currents to which I had reference in my paper. It does not seem to me that the fact that the flow of energy from the engines is not uniform would necessarily establish cross-currents between the machines. It would simply mean that as a generator runs more slowly it gives up less power to the system than when running faster.

2 I agree with Mr. Lincoln that in general the larger the flywheel with any given engine the more uniform will be the rotation, yet I believe it is also true that if there is any tendency for the sets to hunt, the larger the flywheel the greater will be the cross-current that will flow between the machines and the greater will be the electrical disturbances. The natural period of vibration must be avoided in the design of the flywheel and it must be large enough so that the missing of a power stroke is not serious. These difficulties may, however, be corrected by having many cylinders and thus more impulses per revolution, as well as by having a heavy flywheel. In respect to the point under discussion, I would consider that engine the best which, with a given degree of variation from uniform velocity during any given revolution, uses the lightest flywheel.

FREIGHT TRAIN RESISTANCE

By Prof. Edward C. Schmidt, Published in The Journal for May 1910

ABSTRACT OF PAPER

The paper deals with the results of tests made upon the Illinois Central Railroad by the Railway Engineering Department of the University of Illinois to determine the resistance of freight trains.

Train resistance is defined in pounds per ton and speed in miles per hour, and expressed for trains of various average weights per car, the marked influence of car weight being indicated by the following facts:

At a speed of 5 miles per hour the resistance of a train in which the cars average 75 tons in gross weight is 3 lb. per ton, whereas for a train whose average car weight is 15 tons the resistance is 7½ lb. per ton, a difference of 150 per cent. At higher speeds the relation between resistance values is about the same as at low speeds. At 40 miles per hour, for example, the resistance of a train of 75-tons average weight per car is 5½ lb. per ton, while for a train of 15-tons average weight per car it is 13½ lb. per ton.

The trains tested varied in weight up to 3000 tons. The tests were made over main-line track of good construction, laid with 85-lb. rail, during weather when the temperature was above 30 deg. and when the wind velocity did not exceed 20 miles per hour. The test data are displayed in the paper and the results fully discussed.

DISCUSSION[1]

T. S. Bailey. In Par. 36 it is stated that the lowest temperature recorded at any time during any test was 34 deg. fahr. and the highest 82 deg. fahr. It is further noted that the temperatures at the beginning and end of tests are recorded and that no mean temperature for the whole run is given. It would appear that a correction for temperature is essential, as the variation in density of air between 34 and 82 deg. fahr. is about 10 per cent, which of course affects the resistance by an equivalent amount. While the author has given but meager details of his calculations, there is nothing to indicate that such correction has been made. It would appear reasonable, considering the amount of work and care that has been expended in obtaining these data, that all possible refinements should be applied and that all resistance curves be confined to certain temperature limits. It is believed that, where the temperature difference between the start and finish of any test is great, correction should have been made and an average temperature for the run obtained.

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[1] This paper was presented in St. Louis on May 28 at a joint meeting of the Society with the Engineers Club of St. Louis and at the Spring Meeting at Atlantic City on June 2. The discussion at both meetings has been combined.

2 The writer believes also that the greater resistance in winter is to some extent explained by the greater density of the air.

Prof. Wm. G. Raymond. Professor Schmidt has accomplished at least one good thing by his experiments on freight train resistance in that seemingly he has conclusively settled the disputed point of the increase of resistance with speed. The writer has never been able to accept the statements recently made that freight train resistance is essentially a constant between speeds of 10 and 35 miles per hour, and this set of experiments seem conclusively to disprove such statements.

2 It seems desirable to discuss these tests with reference to the makeup of the trains as well as with reference to the weights. Professor Schmidt mentions the possibility of expressing the facts presented in Fig. 11 by a single equation involving only the first power of the three variables, R, S, and W, and it is desirable that a single expression be found if possible.

3 In attempting to find such an expression, the writer discovered that one law apparently fits the observations for trains with an average car weight of 45 tons and upwards; another law fits those between 25 and 40 tons; but it was impossible to determine whether the curve for the light 15-ton car belongs within the heavier or the medium weight group.

4 In looking for a reason for this it seems that all of the very heavy trains are made up largely of loaded gondola cars, and the lightest trains are likewise largely made up of empty gondola cars, whereas almost all of those trains having an average car weight between 25 and 40 tons are wholly or largely made up of box cars. It is entirely conceivable that these cars, with their greater surfaces, may give resistance following a different law from that applying to the resistance of trains of gondola cars. It would seem that there might very well be two or even three general expressions: one for box cars, one for gondola cars, and possibly one for a combination of the two, although this is perhaps a needless refinement. The values obtained for a train with an average car weight of fifteen tons are perhaps too

small for anything but empty gondola cars, and an equation which is supposed to represent the resistances of average trains (if trains of average makeup can properly be spoken of) should give resistances somewhat higher than those of Professor Schmidt's table for the light-weight trains.

5 The writer has attempted to devise a single equation that will express what the curves of Fig. 11 and the figures in Table 3 show, and has succeeded in finding a comparatively simple one which he has tested for each of the car weights given in Table 3 for speeds at intervals of five miles from 5 to 40 miles per hour. Except for the 15-ton car the discrepancy between the results of the single expression and the results of Table 3 is not more than 6.4 per cent. In no single column is there an average discrepancy of more than 5.3 per cent, and in the table as a whole the average discrepancy is not more than 2.9 per cent. Where quantities are as small as those shown in Table 3 of the paper so that an error of one unit in the last place may mean as much as 3 per cent, and where the inaccuracies of observation are as great as they are in the case of train resistance, this close agreement of a single equation with so many observations would seem to be somewhat remarkable and to warrant its use, since it does express a single general law as against thirteen general laws. The single equation is as follows:

TABLE 1 COMPARISON OF RESULTS BY DIFFERENT FORMULAE

	Car Weights—Tons												
Speed m.p.h.	15	20	25	30	35	40	45	50	55	60	65	70	75
5	7.6	6.8	6.0	5.4	4.8	4.4	4.0	3.7	3.5	3.3	3.2	3.1	3.0
	8.6	6.9	5.8	5.1	4.6	4.2	3.9	3.7	3.5	3.4	3.2	3.1	3.0
10	8.2	7.3	6.5	5.8	5.2	4.7	4.3	4.0	3.7	3.5	3.3	3.2	3.2
	9.2	7.3	6.2	5.5	4.9	4.5	4.2	4.0	3.8	3.6	3.4	3.3	3.2
	8.8	7.9	7.0	6.3	5.6	5.1	4.6	4.2	3.9	3.7	3.6	3.5	3.4
15	9.9	7.9	6.7	5.9	5.3	4.9	4.6	4.3	4.1	3.9	3.7	3.6	3.5
	9.6	8.5	7.6	6.8	6.1	5.5	5.0	4.6	4.3	4.0	3.9	3.8	3.7
20	10.6	8.5	7.2	6.4	5.8	5.3	5.0	4.7	4.4	4.2	4.1	3.9	3.8
	10.4	9.3	8.3	7.4	6.7	6.0	5.5	5.0	4.7	4.4	4.2	4.1	4.0
25	11.5	9.3	7.9	7 0	6.3	5.8	5.4	5.1	4.8	4.6	4.4	4.3	4.1
	11.3	10.0	9.0	8.0	7.3	6.6	6.0	5.5	5.1	4.9	4.7	4.5	4.5
30	12.5	10.1	8.6	7.6	6.9	6.3	5.9	5.6	5.3	5.0	4.9	4.7	4.5
	12.3	10.9	9.7	8.8	7.9	7.2	6.6	6.1	5.7	5.4	5.2	5.0	4.0
35	13.5	11.0	9.4	8.3	7.5	7.0	6.5	6.1	5.8	5.6	5.3	5.1	5.9
	13.4	11.8	10.6	9.5	8.6	7.9	7.3	6.8	6.3	6.0	5.7	5.6	5.5
40	14.7	12.0	10.3	9.1	8.3	7.6	7.1	6.7	6.4	6.1	5.9	5.7	5.4

$$R = \left(1.5 + \frac{100}{W}\right)\left(1 + \frac{S}{100}\right) + \frac{S^2}{125\sqrt{W}}$$

6 The resistances computed by this formula are compared with those in Table 3 of the paper in Table 1 herewith, the upper figures being those in Table 3, and the lower figures being those found by the formula. The last term may be simplified without seriously affecting the formula. If it be made $\frac{S^2}{800}$, there will be no discrepancy greater than ten per cent outside of the first column, and the discrepancies in the first column will be very much less except for low speeds.

7 This paper of Professor Schmidt's is the most comprehensive and authoritative discussion of freight train resistance as a whole that has as yet appeared, and the writer has been interested to compare the results of his investigation with the equation devised by Sanford L. Cluett to fit the curve for fully loaded trains published by the late A. M. Wellington, filling in the particular coefficients and numerical quantities to make it conform as nearly as possible to the most recently published values of some three years ago. This equation is

$$R = 3.5 + 0.0055\ S^2 + \frac{16}{(S+1)^2}$$

The last term should not be considered in comparing values from this equation with Professor Schmidt's values because it does not effect resistances at the higher speeds and is introduced simply to give the high resistances at starting, which Professor Schmidt has eliminated. Considering Professor Schmidt's experiments with trains having an average car weight of 45 tons, consisting of box cars and gondola cars almost fully loaded, which could perhaps be called average trains, it is found that this previously published equation agrees almost exactly up to a speed of 20 miles per hour, beyond which the formula gives results too great. This fact suggested modifications of the coefficients of the formula, and it was found that by writing the equation

$$R = 4.1 + 0.002\ S^2$$

an almost exact coincidence would be obtained throughout the entire list of speeds from 5 to 40 miles per hour.

8 If this expression can be multiplied by some coefficient involving W, it may be possible to drive an equation to fit variations in both average car weight and speed. After trying several such coefficients, one was found which, while it produced greater discrepancies in some

parts of Table 3 than does the independent equation above derived, yet in other parts of the table it gives results agreeing more closely than those of the independent equation. On the whole, it is a simpler equation than the latter and gives results averaging as well. The resulting equation is

$$R = (4.1 + 0.002\,S^2)\left[1 + \frac{5}{9}\left(\frac{45 - W}{W}\right)\right] + \frac{16}{(S+1)^2}$$

which may be simplified to

$$(1.8 + 0.0009\ S^2)\left(1 + \frac{56}{W}\right) + \frac{16}{(S+1)^2}$$

and a slight modification of constants may improve the result. The last term will be used only when considering slow speeds at starting and not when considering slow speeds after the train is well in motion. It is considered worthy of note that Professor Schmidt's results for what may be called his average train agree so closely with the modified Wellington curve.

S. A. Moss. We are accustomed to think of the coefficient of friction as a constant, but as a matter of fact, in most cases of film lubrication the coefficient of friction is not a constant quantity, but changes with the load. That is, when there is a complete oil film between the journal and the lining, the actual friction force is not increased by additional bearing pressure. This fact is well known for high-speed journals with a well-maintained oil film, and properly applies to car journals, where there is usually very good lubrication. Hence it is quite natural that the friction per ton should decrease with the load.

F. W. Dean. Attempts have been made for many years to determine train resistance, but each new experiemnt is inconsistent with those which have preceded it and we are still far from the real solution of the matter. This is probably due to the inefficient lubricating system used in car journals. The boxes are filled with wool waste, which is supposed to have elasticity enough to keep it up against the bearing, requiring the lubricant to reach the journal by capillary attraction and by jarring, but it is doubtful whether this method is very efficient. Again, as the journey goes on the oil may gradually leak out and the lubrication become even less effective. This simple method of lubricating car journals will probably continue, although in Europe they take more pains in this direction than we do in this country.

H. G. Stott. Great caution should be exercised in drawing general conclusions from the data presented by these tests. Comparative tests from which general laws can be deduced should be carried out under identically similar circumstances. If the same test train had been used at the various speeds the condition would have been constant and positive conclusions could have been adopted. It appears, however, that each train was made up of cars differing in kind and number. If a train be composed of empty cars with a loaded car at each end, there will be a vertical component of the draw-bar pull acting downward to increase the weight on the empty cars. The air resistance is also quite considerable and is greater per ton for empty cars than for loaded ones. We have found in operating cars on the Interborough system that on cold mornings the load increases greatly on account of the rigidity of track and cars and the increased journal friction due to the condition of the lubricant. We cannot expect to base any general deductions on these tests because they were not made under precisely similar conditions.

G. N. Van Derhoef. A variation of journal friction with change of load may possibly be due to vibration. Any train running on a railroad has a certain amount of vertical vibration and if the energy required to lift the car is given out on the downward movement, thus forming a closed cycle, no energy is consumed. If, however, this cycle is not a closed one, energy is lost through the track to the earth and must be made up by increased draw-bar pull of the locomotive.

2 The number of wheels is usually identical for both heavy and light cars, making the number of points through which these forces are carried to the rail the same in number, but the heavy car will move through an entirely different wave period from that of the light car. The amplitude of vibration will be less for the heavier car, making it ride more steadily and permitting it to travel more nearly in a straight line through space. How much of the total energy required to pull the train is used up in vibration it would probably be hard to demonstrate, but it must be considerable. On an entirely different class of machinery which has quite a vibratory factor, I found a considerable amount of energy being dissipated,

appreciably affecting the amount of power required to run the machinery.

3 I believe that the loss of energy due to vibration affects the resistance relatively more than the variation in the pressure per square inch on the journals. If the oil film is intact, as it must be if the journal runs cool, the difference in friction percentage is slight. The greater steadiness of the heavy car may largely explain the difference in resistance shown by these tests.

F. J. Cole. The record of actual tests given in Professor Schmidt's paper is a valuable addition to the literature on train resistance. The fact that tests were made on 91 miles of track specially surveyed immediately preceding the tests by the engineering department of the University adds to the accuracy and thoroughness of this report.

2 The conclusions which merit the most consideration are those relating to the difference in resistance per ton obtained with cars of various weights and capacities. This fact the author comments upon in Par. 2, stating that while it has been known for some years it has found inadequate expression and but little application. This statement agrees to some extent with my own investigations of the subject, although I am under the impression that the fact is more generally known among railroad men and used in their tonnage ratings than the exact wording of the paper would imply. It may be true that the engineering profession and the readers of technical papers have often failed to grasp the full significance of the fact that train resistance does vary to a great extent in relation to the weight and capacity of cars.

3 In a paper for the Railway Age Gazette[1] I reviewed and summarized the available tests and literature on the general subject of train resistance. Some of the conclusions reached therein are as follows:

a The resistance of freight cars varies greatly with their capacity and weight, and whether empty or loaded.

b The decrease in resistance on level, straight track of 50-ton capacity cars (total weight about 72 tons) is of great significance in estimating tonnage ratings on low-grade roads. This decrease in resistance becomes of gradually less importance with increase of grade.

c The resistance of American freight cars is practically the same between the limits of 5 to 10 and 30 to 35 m.p.h.

[1] Railway Age Gazette, Aug. 27 to Oct. 8, 1909.

d The journal friction is greatest at starting, rapidly decreasing and gradually reaching its minimum somewhere around 20 to 30 m.p.h., aftewards slightly increasing or remaining constant.

e The journal friction with good lubrication, within the limits of railroad pressures, probably varies inversely as the square root of the pressure.

f With large-capacity loaded cars at freight car speeds on good track, journal friction forms a large percentage of the total resistance.

g The condition of the track, stiffness of rails, etc., are important factors in train resistance, because much energy is expended on poor track in dampened oscillations which cause an absorption of energy, and concussions which cause principally an increase in flange friction.

4 The tonnage ratings of a number of important railroads, such as the Pennsylvania, and the Chicago, Burlington and Quincy, are based on the fact that the resistance of freight cars varies with the weight.

5 The greater resistance per ton of empty cars than of loaded cars has been recognized in all American tonnage ratings, and different forms of correction introduced having for their object the decrease of tonnage for trains composed either wholly or in part of empty cars. Therefore the fact is recognized that the resistance per ton of the empty or partly loaded cars is greater per ton than for cars fully loaded.

6 The average car weights of 15 to 30 tons in the paper evidently refer to empty or partly loaded cars, the resistance of which must be clearly kept in mind as compared with fully loaded cars of different capacities, as for example, cars of 40,000 to 100,000 lb. capacity.

7 In order to obtain the exact resistance of freight cars between speeds of 5 and 30 m.p.h. it would be well to reduce as far as possible the number of variables so as to simplify the problem. For this reason it would appear desirable, if the conditions of traffic permit, to run the same train repeatedly over the same length of measured track at varying speeds. If a piece of straight level track of only a few miles in length could be selected and be approached on either side at sufficient distance to get up the required speed, the question of resistance at the speeds named could probably be more accurately determined.

8 The Pennsylvania Railroad, in the numerous careful and

thorough investigations made by their test department for a number of years, and Mr. A. C. Dennis' paper entitled "Virtual Grades for Freight Trains," read before the American Society of Civil Engineers December 3, 1903, which gives the results of actual dynamometer tests of over 3000 miles, both agree as to the constancy of freight train resistance between 5 and 30 m.p.h. or at least that the resistance at 30 m.p.h. is not greater than that at 5 or 10 m.p.h. These conclusions, because of the careful and numerous tests involved, demand more than ordinary consideration and constitute one of the chief points of difference from Par. 90 of Professor Schmidt's paper, in which it is stated that there is nothing in the data to support such a conclusion.

9 The condition of the track regarding stiffness, alignment, etc., doubtless has much influence on train resistance. Quoting from Dr. Dudley in his pamphlet Condensed Diagrams of the Inspection of the New York Central and Hudson River Railroad, 1899:

> The ability of one locomotive to draw eighty loaded 60,000-lb. capacity cars in a single train shows what has been accomplished in the way of reducing train resistance by improving the track, motive power and rolling stock. On the light 4½-in., 65-lb. rails the freight train resistance was 7 to 8 lb. per ton, and is now reduced to 3½ lb. on the 5⅝-in., 80-lb. rails for the 60,000-lb. capacity cars and long trains. For 80,000 to 100,000-lb. capacity cars loaded it would be still less.

10 If journal friction within the limits of speeds used on railroads remains constant or very slightly increases for 20 or 30 m.p.h., then it is conceivable, with track conditions so perfect that the oscillations, nosing and slewing are reduced to a minimum, that apart from the greater air resistance there would be little or no increased resistance within the limits of ordinary freight car speeds. On the other hand, gaging, alignment and joints may be in such poor condition that a great deal of energy is absorbed in shocks and dampened oscillations, which may account to a considerable extent for the somewhat conflicting results obtained from dynamometer tests. For a given stiffness of rail and at slow speeds, the effect of the shocks and oscillations would not be so marked, but as the speed increased their effect to absorb energy would be very noticeable.

Prof. W. F. M. Goss. In commending Professor Schmidt's paper, I want first to call attention to the fact that it has resulted from the work of one of unusual experience in the field with which it deals. Professor Schmidt became responsible for the first dynamometer car of the University of Illinois in 1894, and he has since had charge of all work in train resistance which has engaged the joint attention of the University of Illinois and the Illinois Central Railroad. The present dynamometer car, a device of superior merit, is of his design. When B. J. Arnold was securing data which he could use as a basis for the first great work of steam railway electrification in New York City, Professor Schmidt and the Illinois dynamometer car were for a considerable period in his service on the New York Central Railroad and other eastern roads. Each year's work has brought some distinct improvement in methods and in the accuracy and significance of the results obtained. The present paper, therefore, which represents work of the last two years, is to be accepted as the culmination of an investigation which has extended over a period of six or eight years in its entirety.

2 The general subject of train resistance has received generous attention during the past year from F. J. Cole, who has published an excellent review of existing literature. Mr. Cole has given a survey of the whole field of experimentation from which the reader may draw his own conclusions as to the value of any given set of results. Professor Schmidt's paper now comes as a distinct addition to this excellent summary of previously existing data, complete and comprehensive and of undoubted reliability. It shows with exceptional fidelity the remarkable efficiency of the heavy-capacity car. Judged by the results here presented, the saving in power brought about by the introduction of the high-capacity freight car constitutes one of the important achievements in the development of modern railroading. The paper is important also because of the accuracy with which it defines the increase in train resistance with increased rates of speed. It is a significant fact, well set forth by Professor Schmidt's results, that among the factors limiting the speed of freight trains the increased resistance of the train itself with increase of speed is of far less importance than the diminishing tractive power of the locomotive which pulls it.

John Balch Blood. In Par. 2 Professor Schmidt mentions that the variation of resistance with train weight has not found adequate expression, but I think it has been thoroughly appreciated and universally acknowledged that varying car weight affects the independent term of train resistance formulae. In 1903 I pointed out the values of this coefficient in my paper on A Rational Train Resistance Formulae,[1] as follows:

A = 3 for heavy freight trains
A = 4 for average passenger trains
A = 5 for heavy large electric cars
A = 6 for medium electric cars
A = 7 for light electric cars

TABLE 1 RESULTS GIVEN BY FORMULA.

WEIGHT CAR TONS	MILES PER HOUR			
	5	10	20	30
15	8.48	9.04	10.73	12.85
	7.62	8.20	9.56	11.24
	+0.86	*+0.84*	*+1.17*	*+1.61*
20	6.76	7.22	8.55	10.20
	6.77	7.30	8.53	10.00
	−0.01	*−0.08*	*+0.02*	*+0.20*
30	5.05	5.39	6.36	7.54
	5.38	5.80	6.80	8.05
	−0.32	*−0.41*	*−0.44*	*−0.51*
40	4.19	4.48	5.27	6.22
	4.38	4.70	5.50	6.57
	−0.19	*−0.22*	*−0.23*	*−0.35*
50	3.68	3.94	4.62	5.43
	3.72	3.96	4.56	5.52
	−0.04	*−0.02*	*+0.04*	*−0.09*
60	3.33	3.57	4.18	4.89
	3.30	3.50	4.02	4.83
	+0.03	*+0.07*	*+0.16*	*+0.06*
75	2.99	3.20	3.74	4.37
	3.00	3.18	3.74	4.37
	−0.01	*+0.02*	*+0.04*	*−0.10*

Formula figures on first line. Prof. Schmidt's figures on second line. Differences in italics.

2 These tests by their nature have eliminated the head wind resistance which is the main part of the second power term of resistance formulae. Yet when results are put into formulae the form

$$R = a + bM + cM^2$$

is used.

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[1] Trans. A.S.M.E., Vol. 24, p. 950.

Why not instead take the functional variation as shown by the results themselves?

3 I have taken the results at given speeds and plotted the total resistance per car for the different weights. From observation I

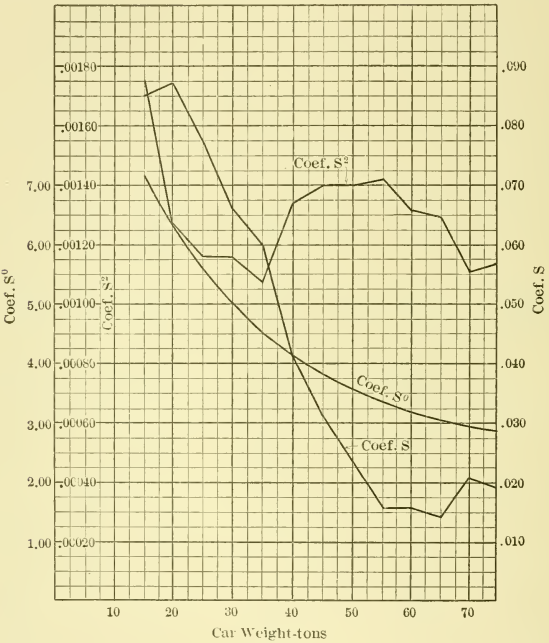

Fig. 1 Coefficients of Formulae in Par. 75 of the Paper

find the resistance common to all to be the side-air resistance, and the function has a value of 1.7. The coefficients of the formulae in Par. 75 were plotted on the smooth curve of rectangular hyperbolic form. This term in reciprocal form would be a linear function, which I found to be

$$\left(1.5 + \frac{100}{T}\right)$$

Taking the exponent 1.7 found above and determining the coefficients for the track and side resistance terms gives a complete formula for Professor Schmidt's resistance without head-air resistance as follows:

$$R = \left(1.5 + \frac{100}{T}\right) + 0.025M + 0.00466 \frac{L}{T} M^{1.7}$$

where R = resistance, T = weight of one car, M = miles per hour, L = length of one car. Results obtained by the use of this formula at various car weights and speeds are compared with those of Professor Schmidt in Table 1. The differences are less than the variations between observations and it will therefore be seen that with proper functions the multiplicity of formulae is unnecessary and misleading.

Lawford H. Fry. I am disposed to agree with Professor Schmidt that the results he gives may be used with reasonable accuracy for

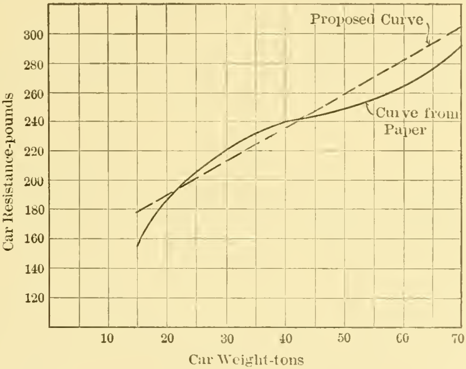

Fig. 1 Comparison of Results by Proposed Formula and by Formulae of Par. 75 of the Paper

calculating the resistance of a freight train, but I should like to suggest a slight change in the method by which the results are expressed. If from the resistance equations in Par. 75 the total car resistance is calculated for a number of car weights at the same speed, the resistances when plotted in relation to the weight as in Fig. 1 herewith give an irregular curve, which does not appear to be required by the experimental data, nor to express any special theoretical point. As a matter of fact, the quantity really measured in the first place was the total car resistance from which the resistance per ton was calculated. A

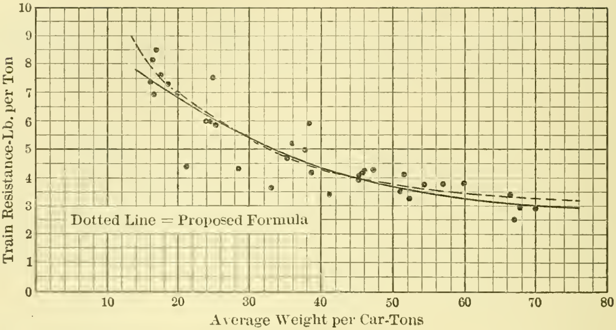

FIG 2 COMPARISON OF CURVES AT 5 MILES PER HOUR (FIG. 3 OF THE PAPER).

slight change in the coefficient of Par. 75 will be sufficient to make the change proposed. For general use, however, I would suggest the formula

$$R = 1.5 + \frac{106 + 2S}{W + 1} + 0.001S^2 \ldots\ldots\ldots\ldots [1]$$

where R is the resistance in pounds per ton of 2000 lb.
W is the weight of the car in tons
S is the speed in miles per hour

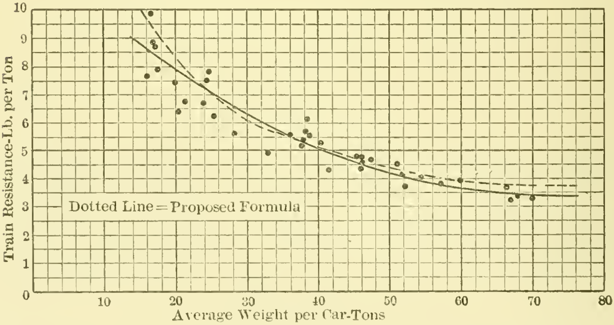

FIG. 3 COMPARISON OF CURVES AT 15 MILES PER HOUR (FIG. 5 OF THE PAPER).

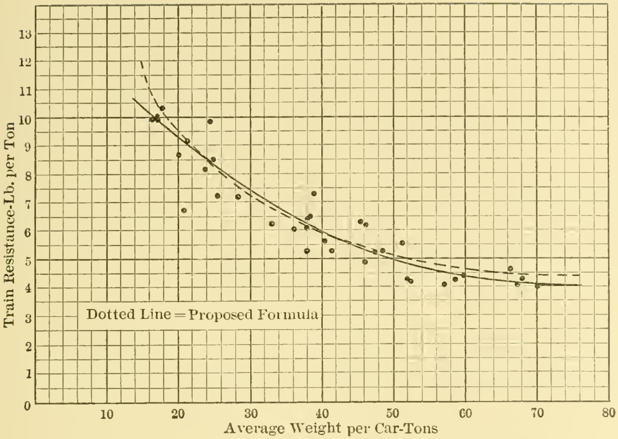

FIG. 4 COMPARISON OF CURVES AT 25 MILES PER HOUR (FIG. 7 OF THE PAPER)

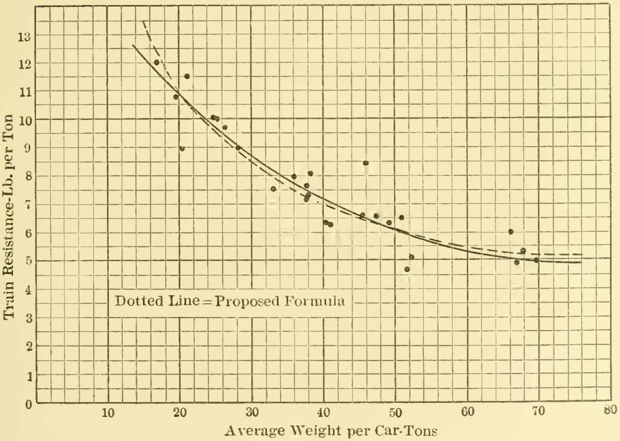

FIG. 5 COMPARISON OF CURVES AT 35 MILES PER HOUR (FIG. 9 OF THE PAPER)

Formula 1 expresses quite closely Professor Schmidt's results for all combinations of weight and speed. To show the difference between the proposed formula and the original curves I have redrawn Figs. 3, 5, 7 and 9 of the paper (Fig. 2 to Fig. 5 herewith), adding in dotted lines the resistance given by the proposed formula. It will be seen that for all car weights down to 20 tons the two lines lie close together and that for lighter weights the new curve does no violence to the experimental data and gives figures which lie on the safe side of the original curves. The formula proposed is not offered as being more accurate than Professor Schmidt's, but simply as a more convenient form of expressing all of his results.

ROBERT MOORE[1]. Professor Schmidt's paper presents for the first time, so far as I know, facts of great interest and suggests some very important conclusions. For example, it justifies very completely the general tendency toward heavier cars, the reasons for which have not been as well understood as they can be now.

2 I should like to know whether the author has worked out any theory as to the cause of this difference in the resistance of heavy and light cars. The high cost of handling freight in European countries is probably due to the use of cars so small that we could not afford to run them. Cars of the size that we send to the scrap heap are in regular use in Europe. This is an exceedingly valuable and suggestive paper and clearly points out the doom of the small car. The thanks of all engineers are due to those who have so clearly demonstrated that fact.

CHARLES WHITING BAKER. This paper offers a great deal of food for thought to the engineer who is interested in traction matters. It shows that the resistance per ton for a loaded freight car is very much less than that for the same car when it is empty and is less for the modern 50-ton capacity car than for a light old-fashioned 10-ton car. This seems to indicate that to design a machine for small friction loss it is necessary to load the journal to the limit of safe practice and not to be content with light loads of 50 lb. per sq. in.

2 The difference in hauling capacity with different sized cars cannot be due to air resistance, because at the slow speed at which these tests were made this is very small.

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[1] Consulting Engineer, Merchants Laclede Bldg., St. Louis, Mo.

Prof. H. Wade Hibbard. Examining the curves in Fig. 11 it will be noticed that at 15 miles per hour the resistance of the 75-ton car is 3½ lb. per ton, while the resistance of the 15-ton car is nearly 9 lb. This difference is so great that the official who is charged with getting economic results from freight transportation should carefully consider the question of discarding small cars. When I was with the Lehigh Valley Railroad orders were issued to scrap certain small cars, of which we had many, as soon as they cost $16 for repairs. The application of engineering principles to the freight car will determine at what point the car ceases to earn its right to existence. The annual report of the Interstate Commerce Commission shows a great difference in the cost of hauling freight per ton mile on different roads. The Pittsburg and Lake Erie Railroad shows a very low cost per ton mile, due largely to the use of big cars and partly to the fact that they carry a heavy coal traffic northward to the lake and a heavy ore traffic southward to Pittsburg, thus hauling few empties.

2 A glance at the curves of Fig. 10 shows that they assume a horizontal aspect for a car weight of 75 tons, which seems to indicate that the 75-ton car is large enough and that an increase in weight would show little or no decrease in resistance. It is a very common practice among Americans to continue making things larger, but I am inclined to think from these curves that we have reached the limit of car size, as regards lessened tractive resistance per ton.

3 We are entering upon an era of scientific railroad engineering. We are getting out most thorough specifications and are applying engineering investigations to all sorts of mechanical equipment. The locomotive, for instance, is being born anew as an engineering structure through the efforts of trained engineers.

4 In my judgment heavy tonnage cars are easier to pull because they are made of steel and are very stiff over the truck centres, so that the trucks are free to swivel more easily when they are on curves and more readily take their natural positions on tangents.

5 Many years ago when Mr. J. W. Kendrick was with the Northern Pacific Railroad he had his road gone over with the dynamometer car for the purpose of adjusting locomotive ratings and consequent size of tranis. The result of adding a single car to each train would be a considerable increase in the productive capacity of any road.

6 It is not necessary for a road to go to the expense of a complete

dynamometer car such as Prof. Schmidt used. I have employed a hydraulic drawbar about four feet in length between the tender and train as a substitute and I believe that such an instrument will produce results and information of much value at a slight expense.

J. P. Clayton[1] mentioned the possibility of the curves in Fig. 10 turning upward again with heavier cars since they do not become isentropic in the last part of the curve as drawn.

F. W. Marquis. Professor Hibbard believes that we have reached the limit with a 75-ton car and I believe that this is true of the present design, but by increasing the bearing area the size of the car might be increased without increasing the resistance.

The Author. I have been especially interested in the formulae proposed by Dean Raymond, Mr. Fry, and Mr. Blood. While I believe that in the ordinary applications of the data the table is the most convenient expression of the results, I appreciate thoroughly the usefulness of such general formulae as have been proposed. The reasons for not including them in the original paper are set forth in Par. 74. Since, however, the discussion has brought forward suggestions for a general expression of the results in terms of R, S, and W, it seems well to present some of these which were deduced during the preparation of the manuscript. Among those which most accurately represent the experimental results are the following:

$$R = \frac{S + 41}{0.171\ W + 3.8} \dotfill (A)$$

$$R = \left(1.5 + \frac{100}{W}\right) (1 + 0.01S + 0.0003S^2) \dotfill (B)$$

$$R = \frac{41.6}{W^{\frac{5}{8}}} (1 + 0.01\ S + 0.0003S^2) \dotfill (C)$$

2 Formula A gives a maximum deviation from the results of Table 3 of about 10 per cent when $W = 75$. For other values of W the error varies from $4\frac{1}{2}$ to $7\frac{1}{2}$ per cent. Formula B results in a maximum error of about 10 per cent, but this occurs when $W = 15$. For other values of W, formula B gives a maximum error of about 7 per cent. The maximum error resulting from the use of formula C at any part of its range is about 7 per cent.

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[1] Assistant in Railway Engineering, University of Illinois, Urbana, Ill.

TWO PROPOSED UNITS OF POWER

By Prof. Wm. T. Magruder, Published in The Journal for June 1910

ABSTRACT OF PAPER

The paper gives a history of the terms "horsepower," "commercial horsepower," "Centennial horsepower," "unit of commercial evaporation," "unit of evaporation," "kal," "boiler horsepower," and shows how they have been changing in definition and value, with a comparison of the values in B. t.u. of the units of evaporation and of boiler horsepowers. An objection is made to the use of the term horsepower as applied to steam boilers, since as the output of a steam boiler is heat energy, it should be so measured. The capacity or power of a boiler and its output of energy should therefore be measured in "boiler-powers." A boiler-power is defined as 33,000 B.t.u. of heat energy delivered per hour by a steam boiler, steam main, hot-water heating main or the like, or added per hour to the feed-water of a boiler, or to the water of a hot-water heating system.

Similarly, an objection is raised to the term "horsepower" as the unit of measurement of the output of heat energy of a blast furnace, coke oven, gas producer, gas main or oil well. The statement is made that 10,000 B.t.u. of heat energy per hour are required for the development of a mechanical horsepower, as the average of the best gas engine practice today. It is proposed that the heat energies of gaseous and liquid fuels be measured in "gas-power," a gas-power being defined as 100,000 B.t.u. of heat energy delivered per hour by a gaseous or liquid fuel.

DISCUSSION

William Kent. As one of those who took an active part in the establishment of the unit of boiler horsepower, as chairman of the Boiler Test Committee of 1884 and a member of the committee of 1889, it may be well that I should give my present views on the subject.

2 In the meetings of the committee of 1884 the question of the boiler-horsepower unit was thoroughly discussed. Among other units urgently favored by one or more members, but finally rejected, were the one now proposed by Professor Magruder, 33,000 heat units per hour; one proposed by myself, 30 lb. of water from and at 212 deg.; and one proposed by someone else, 30 lb. from 212 deg. into steam at 70 lb. pressure, which at that date was the unit adopted in specifications for contracts by the Babcock and Wilcox Company.

3 The unit adopted by the Centennial committee was 30 lb. of water evaporated into dry steam per hour from feed water at 100 deg. fahr., and under a pressure of 70 lb. per sq. in. above the atmosphere. The committee of 1884 adopted the same unit, but in order to express it both in terms of "from and at 212" and in heat units, they stated that it "shall be considered to be equal to 34½ units of evaporation, that is, to 34½ lb. of water evaporated from a feed water temperature of 212 deg. fahr. into steam at the same temperature. This standard is equal to 33,305 thermal units per hour." Taking the steam tables available in 1884, the total heat above 32 deg. of steam of 70-lb. gage pressure was 1778.24, and the total heat of water at 100 deg. was 68.08. The difference, 1110.16, divided by 965.7, the latent heat at 212 deg., gives 34.488 instead of 34.5. The product of 30 × 1110.16 is 33,304.8 thermal units.

4 The term "unit of commercial evaporation," quoted by Professor Magruder from the Centennial tests, and recalculated by him with different values in Par. 8, was not used by the committee of 1884 nor by the committee of 1889. It always was a useless unit, and there is no need of considering it now.

5 The committee of 1899, recognizing the facts that 100-deg. feed water and 70-lb. steam pressure no longer represented prevailing steam practice, as they did in 1876; that there was a general tendency to use the term "from and at 212 deg." in contracts for boilers; and that some scientific engineers wished to use the thermal unit in their calculations and reports, agreed to drop the condition of 100-deg. feed and 70-lb. pressure as the basis of the definition of the standard, and to take 34½ lb. from and at 212 deg. as the basis. This involved a recalculation of the heat units, which then became 33,317 instead of 33,305.

6 For the 33 years from 1876 to 1909 there has been no confusion or complication in the standard of boiler horsepower beyond the insignificant difference of 12 lb. in 33,300, and since 1899 there has been a universal acceptance of 34½ lb. from and at 212 deg. as the exact standard. The settled practice of 33 years, which has gone into the literature of steam boilers, and on which contracts are based, should not be changed without very strong reasons.

7 There is, however, a very good reason for changing the figures used in expressing boiler performance on a heat unit basis, and the factors of evaporation used for converting the evaporation under any stated condition into equivalent evaporation from and at 212 deg. It is that the old steam tables, based on the results of Regnault's

experiments of over 60 years ago, are now known to be slightly in error, and more accurate tables are now available. According to the new tables of Marks and Davis the latent heat of steam at 212 deg. is 970.4 B.t.u., and the heat equivalent of the boiler horsepower, or 34½ units of evaporation, is 33,478.8 B.t.u. By Peabody's tables the corresponding values are 969.7 and 33,454.65, the difference being only about 0.07 per cent. This difference is due chiefly to the use of different values for the thermal unit, which according to Marks and Davis is $\frac{1}{180}$ of the heat needed to raise 1 lb. of water from the freezing point to the boiling point at mean atmospheric pressure, and according to Peabody is the heat needed to raise the temperature of 1 lb. of water from 62 to 63 deg. fahr.

8 The actual difference which arises from the use of the two tables may be shown by an example: Suppose a boiler evaporates 10,000 lb. of water per hour from 100 deg. fahr. into steam at 70 lb.-gage pressure, and uses 1000 lb. of combustible per hour, the heating value of the combustible being 15,000 B.t.u. per lb. Required the horsepower, the equivalent evaporation per pound of combustible, and the efficiency.

		Old Tables	Peabody	Marks and Davis
a	Total heat of 1 lb. of steam at 70.3-lb. gage	1178.3	1183.1	1183.4
b	Total heat of 1 lb. of water at 100 deg. fahr.	68.08	68.0	67.97
c	Difference	1109.22	1115.1	1115.43
d	Divide by latent heat at 212 deg.	965.7	969.7	970.4
e	Factor of evaporation	1.14862	1.14994	1.14945
f	Equivalent pound per hour from and at 212 deg.	11,486.2	11,499.4	11,494.5
g	Horsepower (equiv. evap. ÷ 34½)	332.93	333.32	333.17
h	Heat units absorbed per pound combustible (*c* x 10) =	11,092.2	11,151.0	11,154.3
i	Efficiency, per cent. (*h* ÷ 15,000)	73.95	74.34	74.36

9 While the difference in the latent heat of steam at 212 deg. in the new tables is 0.07 per cent, the difference in the practical results is only about 0.04 per cent, since the total heats differ in the two tables.

10 The complication of which Professor Magruder complains will disappear if either one of the two new tables is used. There is no chance for confusion, misunderstanding, or "litigation between contractors on the accuracy of the fulfilment of the terms of a contract" if the contract defines a boiler horsepower as the equivalent evaporation of 34½ lb. of water from and at 212 deg. fahr. and specifies that in

computing the equivalent evaporation Marks and Davis' or Peabody's table shall be used. If the tables are not specified, an engineer using the old tables might report the horsepower developed in a test as 332.93, while if he used Peabody's tables he would report it as 333.32, and if he used Marks and Davis' tables 333.17, scarcely a large enough difference to be the cause of litigation.

11 I prefer to use Marks and Davis' tables myself, because I think the heat unit upon which they are based, $\frac{1}{180}$ of the heat required to raise 1 lb. of water from the freezing point to the boiling point at atmospheric pressure, both of the points being those of physical phenomena which are independent of the graduations of a thermometer, is more capable of precise determination than the heat unit defined as the heat required to raise 1 lb. of water from 62 deg. to 63 deg. fahr. Other good reasons for the adoption of this unit are given in the preface to Marks and Davis' tables.

Edwin D. Dreyfus. Cases frequently arise in which comparisons must be made between a gas plant and a steam plant. Considering that in many installations there are different proportions of heat and power required, it becomes extremely important that we keep them on some rational basis, so as to avoid confusion. Inasmuch as we have definite standards for powers, we could consider the amount of energy delivered by the boiler or producer to the heat transferring medium, either steam or gas, as equivalent to so many heat units, in potential, sensible or latent heat; and then determine how much power could be developed from that heat, depending on the thermal efficiency of the steam or gas motor.

H. G. Stott. In discussing any unit of power it is always best to have a definite name for it. The names for units, especially electrical units, have all been given to prominent men who have made great research in the sciences or arts connected with electrical engineering.

2 It occurs to me that we have here an opportunity of perpetuating the name of a man, although he really does not require it because his name will always live in engineering science. Why not call this unit a "Thurston"?

3 It is proposed to reduce the horsepower from 33,479 B.t.u. per hr. according to Marks and Davis, to 33,000. The horsepower is irrational and empirical, while the kilowatt-hour, which is based upon the c.g.s. system, provides a rational unit. One kilowatt hour is

equal to 3412 B.t.u. Why not make a multiple of this quantity, 34,120 B.t.u., the unit for boilers and producers? This would raise the unit 641 B.t.u. instead of decreasing it by 479 B.t.u., as proposed by Professor Magruder. Dividing by ten would give a direct comparison of the efficiency from the steam or fuel to the switchboard.

I. LUNDGAARD.[1] A more striking example of chaos than the utter disorder and confusion that exist in the English system of technical units can hardly be conceived, and the most remarkable thing is that it is tolerated. What we need is not *more* but *fewer* units. There is a unit for heat; but that does not prevent us from having at the same time a unit of refrigeration, a unit of evaporation, a boiler horsepower; and the paper under discussion proposes a boiler-power, and a gas-power.

3 Manifestly we should have no unit of heat, since heat is energy, and the unit of energy is directly applicable. We would then save the conversion of British thermal units to foot pounds for calculations of efficiencies of heat cycles. But energy is measured in foot pounds and horsepower-hours, so we have the same multiplicity of units in this case.

4 The paper under discussion is unfortunate both in its aim and in the selection of the names of the new units. The two proposed units are unnecessary, and they add another calculation to our labors and are therefore harmful. They convey no familiar impression or resemblance to our minds that would facilitate their comprehension and remembrance. Until we adopt some better units, let us use the British thermal unit; or, in cases where this unit is too small or too large, let us use some decimal part of it.

THE AUTHOR. I quite agree with Mr. Kent that standards should not be changed except for very strong reasons. But he proposes to change again the standard for a boiler horsepower to suit the new steam tables and the new definition of a British thermal unit as proposed on page 6 of Marks & Davis' steam tables. Mr. Kent loses sight of the fact that I am not proposing a change in the definition and value of the boiler horsepower, as he does, but rather a more logically named unit and a fixed value for it which will not have to be changed with each new investigation on the heat of water and steam, to be called a "boiler-power" rather than a "boiler-horsepower." I propose to substitute the use of the term "boiler-power" for the term "boiler-horsepower," the former being definite and fixed and the latter being variable in value.

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[1] Associate Engineer, Rochester Railway and Light Co., Rochester, N. Y.

2 Accepting Mr. Kent's example, it will be seen that a difference of 0.41 per cent in the efficiency of a boiler as calculated by the old tables (73.95 per cent) as compared with its efficiency as calculated by either of the later steam tables (74.34 per cent or 74.36 per cent) is enough to cause misunderstanding. The use of the British thermal unit, or its multiple, in all commercial and scientific measurements of the heat absorbed and given out by a boiler would free us from the complications incident to "from and at."

3 If we accept Mr. Stott's suggestion that a "Thurston" is 34,120 B.t.u. of heat energy delivered per hour by a boiler, let us add that an "Otto" is 10,000 B.t.u. of heat energy delivered per hour by a gaseous or liquid fuel.

4 I cannot agree with Mr. Lundgaard in his statement that we should have no unit of heat, but should measure it solely in foot-pounds, simply because "heat is energy." As electricity is another form of energy, would he require us to measure the capacities and outputs of dynamo machinery in foot-pounds rather than in joules and watts? However, I agree with his conculsion to use the British thermal unit and multiples of it, and therefore proposed 10,000 B.t.u. per hour as one gas-power, and 33,000 B.t.u. per hour as one boiler-power. The object in writing this paper was not to increase the number and complexity of the units already in existence, but to simplify the units of capacity, or output, of steam boilers and gas-producers before a more complex and irrational unit shall become fixed by use for the latter.

OPERATING EXPERIENCES WITH A BLAST FURNACE GAS POWER PLANT

By H. J. Freyn, Published in The Journal for June 1910

ABSTRACT OF PAPER

The plant under discussion in the paper consists of four 2000-kw. gas engine generators receiving blast furnace gas cleaned in a preliminary and a secondary washing plant. The former consists of two tangential dry dust catchers and two wet scrubbers, or hurdle washers, while in the latter plant Theisen gas washers are used. The gas supplied by six blast furnaces, had in 1909 an average heat value of 98.3 B.t.u. per cu. ft., and contained 26.51% CO, 3.57% H, and 0.196% CH_4. The temperature of the gas entering the gas-cleaning plant averaged 332.5 deg. fahr., which was reduced during the cleaning process practically to atmospheric temperature at the engines. The average raw gas pressure was 9.29 in. of water, while gas of 4-in. pressure was delivered by a 100,000-cu. ft. gas holder. The average amount of flue dust in the dry-cleaned gas was 1.53 grains per cu. ft., which during the washing process was reduced to 0.0058 grains per cu. ft. The wet scrubbers took out 80% and the secondary cleaning plant 98% of the amount of dust received. The total efficiency of the gas-washing plant was 99.5%. The amount of moisture in the engine gas averaged 5.62 grains, against 3.49 grains in the atmospheric air. The amount of water used for gas cleaning averaged 102 gal. per 1000 cu. ft. of gas cleaned, 83 gal. of which was used in the wet scrubbers, and 19 gal. in the Theisen washers. The power consumed in the gas-cleaning plant was 3.3% of the gas engine output. The load factor for the year was 72%, and the average running time was 77% of the total possible time. The thermal efficiency of the plant at the engine shaft, as determined continuously by Venturi meter, averaged 20.8% for 1909. The total output of the station was 50,494,100 kw.

ADDITION

The following addition to his paper was given orally by Mr. Freyn in presenting it before the Society at the Spring Meeting and should therefore be considered a part of his paper.—Editor.

APPENDIX NO. 6

SUMMARY OF OPERATING RESULTS DURING THE FIRST FOUR MONTHS OF 1910

In January 1910, the first gas blowing engine was started very successfully, and since that time two more have been put in operation, furnishing blast to three furnaces. One of these engines is blowing blast furnace No. 4 without the aid of steam blowing engines, delivering 40,000 cu. ft. of air per minute.

2 The change in the arrangement of the preliminary gas cleaning plant mentioned in the paper was put into effect in January and the results obtained by operating four wet scrubbers in parallel are very satisfactory.

3 The addition of gas-blowing engines and the larger output of the gas-electric station has very materially increased the quantity of power gas consumed, so that at present about 27,500 cu. ft. of gas are being purified each minute with four gas-electric and three gas blowing engines in operation. The average quantity of gas cleaned per minute for the first four months of 1910 was 20,845 cu. ft. or about 25% more than the average for the year 1909 and 46% more than the corresponding average from January to April 1909.

4 Inasmuch as five blast furnaces have been in operation since the beginning of the year, and since gas blowing engines are supplying a large percentage of the blast to these furnaces, the gas supply has always been more than sufficient, the surplus gas being utilized at present to fire the boilers at the adjacent plate mill, which heretofore had been fired with coal.

5 The average output of the gas power plant for the first four months of 1910 was 5663 kw., corresponding to a load factor of 70.8%. The average time of operation of the plant for this period was 557 hours per month or 77.5% of the total possible time. Repairs on the engines were responsible for 17.5%, while operation of the plant caused 5% of the shutdowns. In no instance was lack of gas responsible for lost time during this period. The gas pressure of the raw blast furnace gas averaged 10.6 in. of water, while the average gas pressure after the secondary washers was 14.9 in.

6 Under present conditions, with blast furnace No. 1 out of blast and the plate mill boiler house receiving gas, the bulk of the gas for the engines is being furnished by furnace No. 3. This was most strikingly proved a few weeks ago, when for certain operating reasons the watering of the stock on this furnace was abandoned. The consequence was a tremendous increase in the amount of flue dust carried into the gas cleaning plant, which became so serious that the watering of the stock on this furnace had to be resumed. Since furnace operation during this period was remarkably smooth and uniform no difficulties or troubles were encountered in the operation of the gas engines from backfiring and premature explosions, nor did sudden changes in the quality of the gas occur.

7 The average composition of the blast furnace gas delivered to the engines for the first four months of 1910 was 14.8% CO_2, 25% CO, 3.59% H and 0.22% CH_4, with a computed heat value of 93.15 B.t.u. and a heat value of 92.9 B.t.u. per cu. ft. determined by calorimeter. The ratio $\frac{CO}{CO_2}$ was 1.69, materially lower than for the corresponding period of 1909, when it was 2.1, indicating low coke consumption and a more rational operation of the furnaces.

8 The average temperature of the gas entering the gas cleaning plant was 255 deg. and 84 deg. before the wet scrubbers. The reduction in temperature due to radiation through the unlined zigzag flue was therefore 67% in 1910 against 66.6% for the corresponding period of 1909, the average air temperature being 40 deg.

9 Since the velocity of the gas traveling through the pipes is materially greater on account of the larger quantity of gas purified, only small quantities of flue dust are being deposited in the dust legs of the zigzag flue and the gas delivered to the wet scrubbing plant is considerably dirtier than it was last year. The amount of flue dust in dry cleaned gas averaged 1.8061 grains per cu. ft. with a minimum of 1.3979 grains in January and a maximum of 2.3361 grains in April. The wet scrubbers, only two of which were operating in series up to May 1910, removed from the gas an average of 91.5% of the flue dust, delivering clean gas containing an average of 0.1488 grains per cu. ft. This high efficiency of the wet scrubbers is maintained with four scrubbers operating in parallel. With over 27,000 cu. ft. of gas cleaned per minute, the four wet scrubbers have removed in May 1910. an average of 96.1% of the impurities received. The average temperature of the clean gas delivered to the Theisen washers was 52 deg., the gas entering the gas holder at 50.55 deg. These temperatures were lower than the temperature of the water supply, 55.41 deg., since the average air temperature did not exceed 40 deg. for the first four months of the current year. The temperature of the waste water from the first wet scrubber was 86.85 deg. on account of the larger quantity of gas passing per minute, and the temperature of the waste water from the second scrubber, 56.38 deg., was only a little higher than the temperature of the water supply, proving that the cooling effect took place almost exclusively in the first wet scrubber.

10 The amount of moisture in the clean gas was 4.735 grains per cu. ft. and the fine gas carried 3.658 grains against 1.994 grains of moisture in the atmospheric air. The larger amount of moisture in 1910 is due to the reduced water consumption and to the larger quantity of gas purified per minute, which reduced the time during which the cooling and condensing effect of the water and the atmosphere acted on the gas.

11 The efficiency of the secondary cleaning plant was over 96%, with a minimum of 95% and a maximum of 97% in January and April respectively. The amount of flue dust in the fine gas averaged 0.00632 gr. per cu. ft., being 9% higher than the average for the whole year of 1909, while the amount of gas cleaned per minute was 25% larger. It is to be noted that the overall efficiency of the wet scrubbing and secondary cleaning plants for this period was 99.6%, so that only 0.4% of the amount of dust originally contained in the dry cleaned gas was carried over into the gas engines.

12 The quantity of water used in the Theisen washers averaged 17.5 gal. per 1000 cu. ft. of gas cleaned or about two gallons less than the average for the

whole year of 1909. A marked economy in the amount of water used in the wet scrubbers was realized, only 63.1 gal. of water being supplied per 1000 cu. ft. of gas cleaned. The reduction in the total water consumption amounted therefore to more than 20% compared with 1909, and a further reduction is being tried at present, since it was found that with four wet scrubbers operating in parallel the clean gas is relatively cleaner than it was with series washing in two wet scrubbers.

13 Unfortunately the power consumption, and therefore the cost of cleaning per unit of gas will not be very much affected by such a reduction, since the wet scrubber pumps do not use more than about 10% of the total amount of power consumed in the gas cleaning plant.

14 The average power consumption for the first four months of 1910 was 0.308% for the wet scrubber pumps, 3.011% for the Theisen washers, the total being 3.319% of the combined output of all gas engines.

15 The heat consumption of the gas-electric station with an average load of 91.45% on the engines while in operation was 16,873 B.t.u. per kw.-hr. or, at 96.2% generator efficiency, 12,101 B.t.u. per b.h.p.-hr., so that the average thermal efficiency at the shaft for the first four months was 21.1%. The averages for the individual months were 20.9%, 21.9%, 20.8% and 20.8% respectively.

16 While it has not yet been possible to determine the thermal efficiency of the various types of gas blowing engines recently installed, Venturi meter measurements of the total quantity of gas delivered to the gas holder indicate that the heat consumption of the three engines operating at about 70% of their full load capacity averages about 12,000 B.t.u. per b.h.p-hr., these engines operating at about 70% of their full load capacity. The thermal efficiency of the plant is therefore about 21%. The result of the fuel economy of the gas-blowing engines is a very marked reduction in coal consumption of the plants which are directly or indirectly benefited by the installation of these engines.

DISCUSSION

A. E. Maccoun.[1] Mr. Freyn's statement regarding the excess power from blast furnaces is, I think, a little excessive. Where blast furnace plants are connected with steel works, requiring all their excess power, or are in such locations that they can dispose of their surplus power at a profit, there should be no hesitancy in installing gas engines for at least 85 per cent of the power required in blowing the furnaces and for generating electricity for use at the works or for transmission, but in some cases blast furnaces are not so ideally located. On account of the higher cost of gas-engine installations over those of steam, under such conditions the former naturally could not be recommended. All conditions of this kind should be carefully studied, as in many cases gas-engine installations may be carried too far.

[1] Superintendent of Furnaces, Carnegie Steel Company, Braddock, Pa.

2 I fully agree with Mr. Freyn in not trusting to automatic arrangements for regulating the gas supply, as the gas pressure must necessarily be kept up in any gas system to insure safety. If the gas pressure falls below that of the atmosphere and air enters, there is always great danger of a very serious explosion.

3 We have noticed practically the same condition Mr. Freyn refers to in regard to getting, at times, a supply of ferro-silicon gas, spiegel gas, or ferro-manganese gas at the gas engine in case a furnace on one of these products happens to have its gas entering the main in the vicinity of the gas-washer intake. At the Edgar Thomson plant there are eleven furnaces connected to one gas main, but the different gases seem to equalize themselves in the main according to their pressures, and the quality of gas depends on where it is taken from the main.

4 All blast-furnace gas-engine plants have had more or less experience with back-firing, especially when they are making special grades of iron, such as ferro-silicon, spiegel, etc. The inlet valves of the engine should be designed so that where this occurs for long periods, endangering operations, the relative areas of the gas and air ports can be changed quickly by hand while the engine is in operation between the limits of 1 unit of air to 4 of gas, and vice versa.

5 The discrepancies in the heat values are accounted for by the fact that analyses are made about every three hours, while calorimeter readings are taken almost continuously. Some time ago we had occasion to make an average of 168 gas analyses during one of our tests on a furnace running on 1927 lb. of coke per ton of iron. The results were: $CO_2 = 16.33$ per cent, $CO = 22.73$ per cent, $H = 1.99$ per cent, $CH_4 = 0.04$ per cent, $N = 58.91$ per cent. The calculated heat value per cu. ft. of this gas at 62 deg. fahr. and 30 in. mercury was 80.55 B.t.u. From approximately the same number of Junker calorimeter readings taken at the same time the result was 75.84 B.t.u.'s per cu. ft. The gas from a blast furnace frequently contains over 24 grains of moisture per cu. ft. When the analyses are made it is customary to get the percentage of the different constitutents by volume, excepting the moisture it contains. When the gas is cooled before making the determinations, a large percentage of the moisture is condensed, and by not making allowance for this moisture the gas is figured as of slightly higher thermal value than it actually is. The thermal readings from the calorimeter are usually considered more accurate than those figured from analyses.

6 All of the gas-washing plants for gas engines that have been

installed in this country have been very successful, so far as I know, although I think some of them were built on a more elaborate scale than necessary, merely to be sure that the gas would be thoroughly cleaned. In nearly all the gas-washing plants I am familiar with, the amount of dirt in the gas after washing was found to be less than that in the air. Extra precautions were naturally taken in designing our first gas-washing plants on account of the large percentage of fine ores that usually compose our blast furnace burdens, but in every case the gas cleaning was found to be very thorough.

7 Blast furnace gas, like any other gas, has a saturation point for moisture, depending on its temperature. If it is cooled down low enough it can only contain a fixed amount of moisture, depending on its saturation point, except the moisture which is mechanically contained, and any such moisture is very easily removed with a few baffles in the gas flue. Elaborate dryers are not usually required.

8 The thermal efficiencies for the gas-engine plant of approximately 23 per cent are all that could be expected under the conditions. Higher values have been obtained in tests, but for continuous work the plant efficiencies obtained by Mr. Freyn are very creditable.

9 *Gas Engine Development.* As Mr. Freyn states, the Lackawanna Steel Company was the first to attempt a large blast furnace gas engine installation in this country. They adopted the two-cycle Koerting engine, built in this country from German designs. The United States Steel Corporation decided in 1904 on an initial installation of blast furnace gas engines at the Edgar Thomson furnaces of the Carnegie Steel Company, which was followed by other installations. After a thorough investigation of the various types of engines used abroad the officials of this company decided that the four-cycle gas engine would be best adapted for their use, and that in designing such an engine the lines and construction of the modern heavy-duty American steam engine should be followed as nearly as possible, as this type of engine had proved universally successful. They also endeavored in the design of these gas engines to eliminate as many complications as possible and to arrange all parts so as to be easily accessible for removal and replacement. All the firms starting to build blast furnace gas engines in this country at the time preferred the center-crank construction in place of the American side-crank construction which has proved itself so successful and convenient. It was decided that an over-hung crank gas engine could be made strong enough and that these engines should be of this type. The heavy American rolling-mill engine frame was also insisted upon. The

Westinghouse Machine Company, in coöperation with the engineers of the Carnegie Steel Company, designed our first engines along these lines.

10 The Snow Steam Pump Works, the Allis-Chalmers Company, and others who were starting into the blast furnace gas-engine business also realized the importance of building along American lines and should be mentioned in connection with the development of a successful gas engine suitable for American blast furnace and steel works practice. I do not mean to detract in any way from what our friends abroad have done in developing the gas engine, as we are greatly indebted to them. It required a great deal of courage to go into this business on such a large scale, knowing that these engines would have to prove just as reliable prime movers as modern American steam engines, which have been years in reaching their present state of perfection.

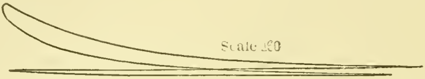
11 The Carnegie Steel Company had built a small tandem gas engine, 21¾-in. diameter cylinders and 30-in. stroke, as nearly along the designs of the larger units as possible. This engine and a 250 h.p. direct-current generator were temporarily installed for experimental purposes at the Edgar Thomson furnaces and were started December 9, 1905. This unit was run continuously under all kinds of conditions and numerous tests were made on it. The information acquired from this experimental engine helped in perfecting the designs of the larger units.

12 *Different Systems of Governing.* At that time it was a great question as to whether a gas engine should be governed by the constant-mixture system or by the constant-compression system. The constant-mixture system, brought to so much prominence by Mess in Germany, consists of governing the mixture of air and gas admitted to the cylinders so as to have an explosive mixture that will readily ignite at all loads, although on light loads the compression must necessarily be greatly reduced.

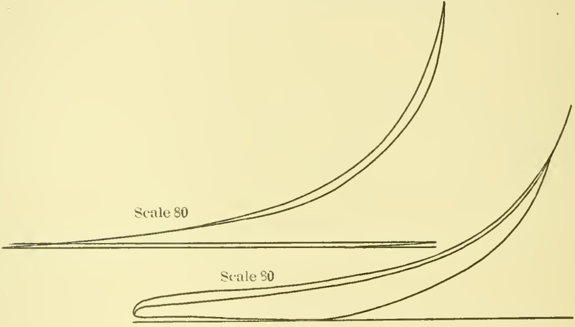
13 The constant-compression system consists in admitting an excess of air into the cylinder with the amount of gas required for any particular load, so that on light loads nearly the same compression will take place as on heavy loads. Efforts were made to stratify this mixture in the vicinity of the igniters so that it would readily ignite on light loads. To effect this stratification many complications were necessarily resorted to.

14 A trial of the constant-compression system proved that when there was no load the charge could not be depended upon to burn and

that at other loads the indicator cards showed a marked difference in area from one explosion to the next at exactly the same load. The full-load cards were the only ones to reach the proper shape. These conditions are characteristic of this type of governing and are due to imperfect combustion at loads under the full rated load of the engine. With the constant-mixture system, however, the cards were of proper shape at all loads, and of the same area for equal loads. (Figs. 1, 3 and 4). Continuous indicator cards showed absence of misfiring at no load and with a compression not over 65 lb.[1]



No Load Card-Constant Mixture System



No Load Card-Constant Compression System

Fig. 1 Comparison of Constant-Mixture and Constant-Compression Cards Taken at No Load

THE TWO LOWER CARDS SHOW THE UNCERTAINTY OF THE CHARGE BURNING AT NO LOAD WITH THE CONSTANT-COMPRESSION SYSTEM. IN ONE CASE THE AREA IS NEGATIVE AND REPRESENTS ONLY THE COMPRESSION LOSS DUE TO A POSSIBLE LEAK. WHILE THE OTHER HAS A POSITIVE AREA, THE COMBUSTION IS NOT WELL TIMED. THESE CARDS WERE SELECTED AT RANDOM FROM A LARGE NUMBER.

15 From the small experimental engine which helped to demonstrate these points, it was found that on light loads with constant compression the charge would not ignite for periods, the engine

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[1] Continuous cards were submitted with the discussion which have not been reproduced for publication. Editor.

would slow down slightly, then take a large gulp of gas and air and fire for a short period and so on, so that it could not be depended upon when light or extremely variable loads were being carried.

16 We therefore adopted the constant-mixture system and have obtained excellent results. It may not be quite as refined and economical as the constant-compression system, but it is better suited for this class of work, particularly on variable loads, although under some conditions excellent results are no doubt obtained with the latter.

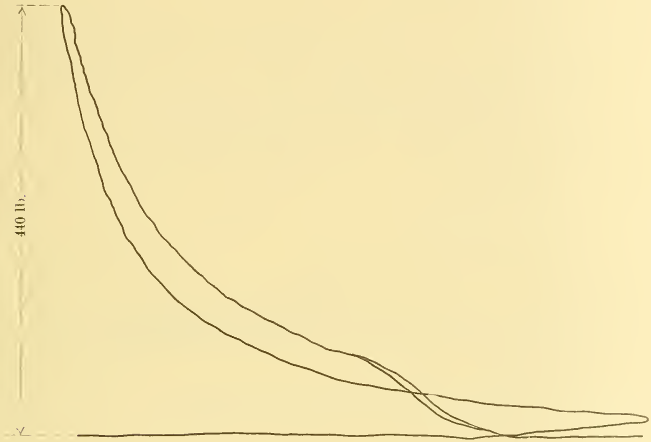


Fig. 2 Indicator Card showing Pre-Ignition, resulting in a Pressure of nearly 500 lb. per sq. in.

CARD SHOWN FULL SIZE; SCALE OF SPRING 160; MAXIMUM CYLINDER PRESSURE RECORDED.

17 It does not seem natural, especially with a four-cycle gas engine, to draw in a very lean mixture of air and gas, compress it to the usual full-load pressure of 200 lb. into a comparatively small volume, and then expect to have the mixture stratified in the vicinity of the igniters so that it can easily be exploded.

18 *Gas Engine Operation.* The installation of gas engines at the Edgar Thomson furnaces consisted of two Westinghouse twin-tandem gas blowing engines, 38-in. diameter and 54-in. stroke, and one Westinghouse twin-tandem unit, 40-in. diameter and 54-in. stroke, for driving a 1500-kw. generator. The first blowing engine was started

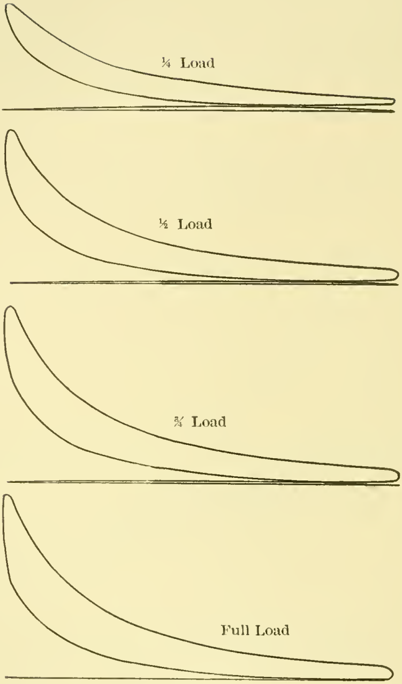
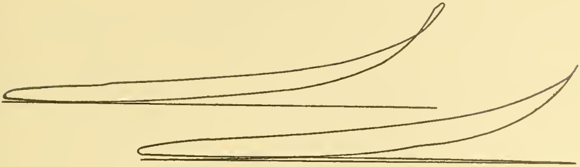
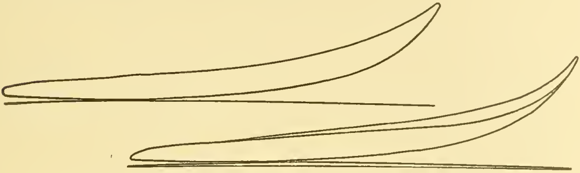


Fig. 3 Cards Taken on the Experimental Engine of the Carnegie Steel Company, when operating on the Constant-Mixture System.

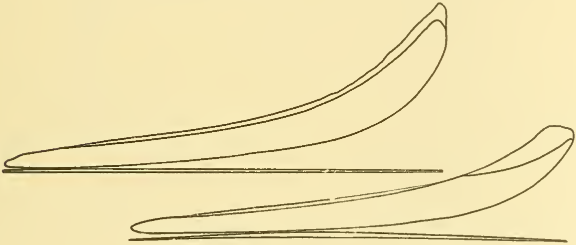
These are to be compared with the constant compression cards shown in Fig. 4. In both series the loads were maintained constant at the different periods. It will be noted that the areas of the constant-compression cards vary from one explosion to another and that those taken at full load were the first to reach the proper shape. This is due to the imperfect combustion at all loads under the full or rated load, a characteristic of this system of governing



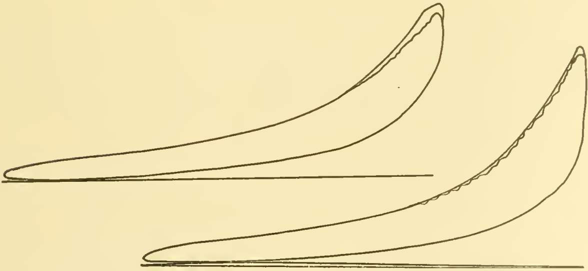
Cards at ¼ Load



Cards at ½ Load



Cards at ¾ Load



Cards at Full Load

Fig. 4 Cards from the Experimental Engine taken on the Constant-Compression System.

on December 7, 1906, and the others followed soon afterwards. From the operation of these engines and from many others that have since been installed, much valuable information was acquired and many improvements in design have followed. All the difficulties encountered since the starting of this plant have been met and overcome and in 1909, No. 1 blowing engine ran 8241 hours out of 8760, or 94 per cent of the time; No. 2 blowing engine ran 8186 hours out of 8760, or 93.5 per cent of the time; and No. 1 electric engine ran 7075 hours out of 8760, or 81 per cent of the time. I would consider these records very good even for the best type of steam engines.

19 *Lubrication.* Great care should be exercised in selecting proper gas-engine cylinder oil and the oil used should be carefully tested. An oil showing the following analysis has been found to be very satisfactory:

Specific viscosity (compared to water) .	4.10
Flash point, deg. fahr..................	530
Burning point, deg. fahr..............	600
Deg. Baume (Sp. Gr. 0.880)...........	28

20 An important test can be made by filtering oil through filter paper, to see if there is any carbon deposit in the oil. This is often due to the temperature of distillation being too high, or to the distillation being carried too far, or to the imperfect filtration of oils that have been heated too high. Such oils will frequently break up and deposit carbon, rendering the oil utterly unsuitable for gas engine use. It is unnecessary to say that a paraffin base oil should be used and never one with a tar base.

21 Our method of oiling cylinders is to pump the oil in when the crank is 50 deg. early of the forward center-line on the suction stroke. There are two oil holes on each end of each cylinder, 30 deg. on each side of the centre. With this arrangement the oil runs down the cylinder walls and is wiped over by the piston.

22 *Ignition Systems.* Mechanical make-and-break and electrical make-and-break ignition systems are used and both work very satisfactorily, but as much care as possible should be taken to make an even distribution of the igniters around the cylinders.

23 Indicator cards taken with one, two and three igniters working show plainly the better efficiency obtained with three igniters in operation. With blast-furnace gas it takes time for an explosion to propagate. This is plainly shown by our being compelled to have the igniters fire from 30 to 35 deg. before the crank pin passes its centre.

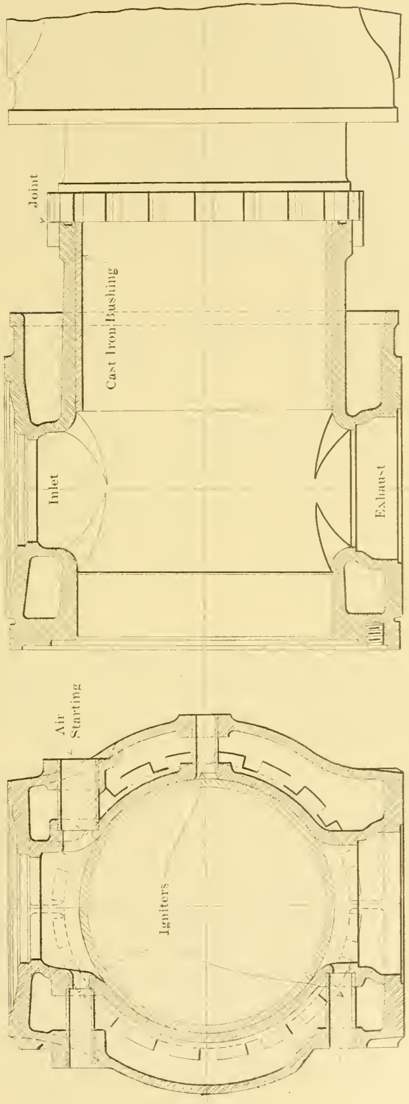


FIG. 5 CAST-STEEL CYLINDER FOR 40-IN. BY 54-IN. GAS ENGINES

If the igniters are all on top of the cylinder, or all on the sides or bottom, most of the wear is on these points, due to the explosion pressure getting under the rings sooner and being greater at these points.

24 *Gas Engine Conditions.* As is well known, the very high explosive pressure at the beginning of the piston stroke subjects the pistons and ends of the cylinders and cylinder heads to severe pressure and temperature conditions, requiring them to be carefully water jacketed and designed to take care of expansion. A blast furnace gas engine, even with these high explosive pressures, rarely averages over 65 lb. m.e.p. in the cylinders.

25 In Fig. 2 is an indicator card showing preignition. The pressure is nearly 500 lb. per sq. in. and in some cases these preignition pressures might be higher. With a 44-in. diameter piston it can be seen that while the explosive pressure continuously transmitted through the working parts of the engine is always large, an additional pressure of 1,000,000 lb. may suddenly be put on the crank pins by preignition. This is why many difficulties such as cracked pistons, heads and cylinders, lubrication troubles, etc., have been encountered, especially on the larger size gas engines. These difficulties, however, are all being overcome and high-class gas engines of large power have been the result.

26 *Gas Engine Cylinders, Pistons and Heads.* The proper water cooling of cylinders, pistons and heads is very important, especially for large engines. The cylinders should have ample waterjacket space between the main cylinder and the outer water jacket should be well fitted with hand holes so that mud deposits can be thoroughly cleaned out.

27 Fig. 5 shows the design of a cast-steel gas-engine cylinder. It has been the aim to make this as simple a casting as possible. The ends next to the explosion were cast down so as to get the best material in that part of the cylinder. It has usually been the practice to make these cylinders of cast iron and with this construction large cylinders required walls approximately 4½ in. thick to resist the heavy explosive pressures. The cylinder shown is of cast steel, bushed with a 1-in. cast-iron bushing, arranged so as to be free to expand lengthwise. This bushing can also be easily removed and replaced.

28 The cast-steel cylinder construction permits us to decrease the thickness of the cylinder walls without decreasing the strength through the cylinder. By this means the water cooling can penetrate much closer to the hot cylinder walls, thus drawing the heat from these vital parts and preventing fatigue of the metal at each end of the cylinder where the heavy explosions take place. This fatigue of the cylinder metal is still more pronounced on gas engines operating on some of the richer gases.

29 There have been some difficulties due to the cracking of gas-engine pistons and cylinder heads, but usually these have been caused by omitting to make the proper provisions for the increased strains and temperature conditions which they are required to stand. In most cases the pistons and heads are now made from cast steel for the larger size gas engines, which permits lighter walls and much more effective water cooling.

30 In all cases the weight of pistons and rods of gas engines should be carried on the crosshead and slippers. The pistons should have at least $\frac{1}{16}$-in. clearance all around the bore of the cylinder, thus leaving only the friction of the piston rings on the cylinder. These rings should be fairly wide and deep and held in place by good strong springs and keepers.

31 Since our engines have been in operation there has been only one case where we have cut a cylinder, and this was due to a water leak.

Joseph Morgan. The Cambria Steel Company has made a small beginning with one gas engine to determine the best way of purifying the gas and also to determine a good type of blowing engine. There is always an experience account in operating plants, which commenced with us when we blew in our No. 7 blast furnace. On the design of an engineer of large experience, we had provided two down-comers for the furnace, each with a large dust-catcher. These dust-catchers were of the usual shape, about 22 ft. in diameter in the cylindrical part, with a cone top and bottom and a fairly large cubic capacity. The down-comer originally entered radially into the cylindrical part pointing downward, at about the same angle as the bottom cone. The gas to boilers and stoves was taken off at the top of the upper cone, and we relied on the large capacity of the two dust-catchers to allow a settlement of the heavy dust to the bottom of the cone, but somewhat to our surprise we got very little dust from the dust discharge openings and very great quantities of dust in the stoves and boiler chambers.

The cause was the action of the heavy volume of gas entering the chamber which, being directed to the center and downward, kept the dirt stirred up from the bottom cone and allowed no settlement. At the first stoppage of the furnace we changed the entrance of the downcomers to a tangential connection in a nearly horizontal direction into the upper part of the cylinder, with the result that the dust caught was largely increased. We also added brick cross-walls on the bottom cone, so that the discharge opening was not closed, but which prevented a current of gas in the bottom cone from stirring up the dust. The dust that came down into the bottom cone was caught in this lower chamber. This detail added to the efficiency of the dry dust-catcher. The resulting increase of efficiency was a valuable lesson on the effect of centrifugal force in separating dust, and the necessity of keeping the gas currents from stirring it up again. In recent improvements on several furnaces we have also added in series with and also following the first dust-catchers, a horizontal dust separator in which the principle of dry centrifugal separation is made use of. We have this apparatus at work on two furnaces, one of which supplies our gas engine.

2 This horizontal separator contains a helical gas-passage through which the gas flows. Each turn of the helix has at its bottom a dust-trap so that the dust carried by the centrifugal force to the outside of the helix goes tangentially into the traps from which it is drawn when necessary. This helical separator traps about ten to fifteen tons daily in addition to that stopped by the large dust-catchers and takes out about 70% of the dust remaining in the gas after leaving the first dust-catcher. The indications are that five or six helical turns are sufficient.

3 This completes the dry separation, which in our plant it is desirable for reasons of cost to make as complete as possible without the use of water, as the dust runs freely from dust-pockets when dry and is therefore handled more cheaply. In our earlier experience we tried several types of wet separators near the furnace, but the great volume of wet dust added largely to the cost of handling. We believe the large quantity of very heavy dust should be taken out as far as possible by dry separation, and that water should be used after the gas has somewhat cooled by radiation. This lessens the quantity of water necessary for final cooling and is another economy.

4 From this separator the gas is taken direct to the stoves and boilers, but for the experimental gas engine we have installed a pair of Schwartz revolving centrifugal washers, somewhat similar to the

Theisen, which are used in series. The water comes out from the first very muddy, while from the second it is very limpid, showing that the former takes out most of the dirt, and the latter perfects the operation. This is perhaps a temporary arrangement, as we have no static cleaners other than the dry dust-catchers or cleaners already described.

5 The engine under trial at our furnace is a double, horizontal, tandem gas-engine with four gas and two blast cylinders, built by the Southwark Foundry Company of Philadelphia. It is novel in several details, all of which have proved of value on trial, as adding to the speed of running and the ease of manipulation. The blowing cylinders are fitted with gridiron slide valves of the well-known Southwark type for inlet and outlet of blast. All the valves for both air and gas cylinders are actuated by the straight-bar reciprocating cam of Southwark type, which allows great facility for adjustment of the cam not found in arrangements of those on rotary shafts. The engine can easily be run at 70 revolutions, a much greater speed than is attainable with ordinary blast valves. This lessens the cost of engine installation or increases the quantity of available air from a cylinder.

6 In addition, there is a tripping device by which the blast inlet valves at one or more of the four ends of the blowing cylinders may be put out of action and left open, thus partly or wholly unloading the engine in starting up or when the furnace needs less blast or even none. This greatly facilitates the starting and manœuvering of the engine, as it need not be started under load or be stopped at casting times or to slacken blast.

7 The other departure from former designs is in the gas-entrance and exhaust valves. The gas cut-off valves located on top of the cylinders are tripped by the action of magnets, the current for operating which is timed by the governor action. The exhaust valves are located so that they are very conveniently accessible, being at the side of the cylinder and above the floor instead of under the floor, as in many gas engines heretofore built. This has been found good practice and there are no difficulties arising from this unusual location. Heretofore it has been supposed that particles of dirt would be more efficiently swept out of the gas cylinder if the exhaust opening were directly under the lowest part of the cylinder, in which case the exhaust valves are not easily accessible.

8 The very full and complete paper of Mr. Freyn, with its voluminous report of working results, is an admirable and valuable addition to the literature of blast-furnace gas engines.

H. G. Stott. The problem of the cleaning of gas is similar to that of removing the moisture from steam. At the 59th Street Station of the Interborough Rapid Transit Company we first used an elaborate system of separators between the engine and the low-pressure turbine. The separator contained a series of baffles, each of which was supposed to take care of a certain amount of moisture. These baffles became loose and in order to keep the machine in operation we removed them. The result was an increase of 4 per cent in the efficiency of the separator. A new separator was designed so as to cause a sudden reduction in the velocity of the steam and we obtained a quality of 97 per cent. I believe the same principle applies to the elimination of dust from gas and that the real separation is effected by the sudden reduction of velocity.

2 I found from tests on the combined unit of reciprocating engines and steam motors that the thermal efficiency works out almost identical with Mr. Freyn's results, a little over 21%, the load ranging from 7000 to 15,000 kw. Any steam motor has the important advantage over the gas engine that it gives a wide range of operation with an efficiency curve that is almost flat. The burning of gas under boilers is a very much more efficient operation than the burning of coal and quite remarkable results have been obtained with gas-fired boilers. It would be interesting to note the results of so using the blast furnace gas and supplying the steam to the combined engine and turbine unit.

Edward A. Uehling. One of the most important parts of Mr. Freyn's paper deals with the cleaning of gas, a phase in blast furnace construction and operation that has been most sadly neglected in the past and even to-day is not fully appreciated except where the gas is to be utilized in the gas engine. But because of the dirt carried into the stoves by the gas their efficiency is greatly reduced, and to make up the deficiency in blast temperature a fourth and not infrequently a fifth stove has been added.

2 The cost of the additional stoves would have been more profitably expended in efficient gas-cleaning apparatus, because better results could be obtained from three stoves supplied with clean gas than from four or even five stoves mucked up by dirty gas. There are few stoves in existence in this country to-day whose heating surface, and consequently heating capacity, could not be quadrupled, if thoroughly cleaned gas was available. This also holds for the boilers connected with blast furnace plants; in most cases their output could

be very much increased and their efficiency doubled if served with clean gas.

3 It is worse than useless to line gas mains and a great deal of money could be saved, not only in refractory material, but also in the metal parts of the main and their supports. There is no excuse for the gas coming off from the furnace at a temperature so high that it will injure an unlined gas main. By applying water, preferably to the stock as it is charged into the furnace, the gas temperature can always be kept below 400 deg.

4. I have been one of the advocates of the blast furnace gas engine for a great many years. Before anything had been done along this line I calculated that there was 800 h.p. available above the needs of the plant for every ton of iron produced in 24 hours. Mr. Freyn has actually obtained about 600 h.p., showing that better results may yet be obtained.

S. K. **Varnes**[1]. American practice in blast furnace gas cleaning has simmered down to the three-phase process. The gas is first passed through dry preliminary cleaners, then through stationary wet scrubbers, and finally through rotary wet scrubbers. The gas is used for two purposes: it is burned in stoves and boilers or used directly in gas engines. Each of these uses requires gas of different characteristics. It has been found in German and American practice that gas containing from 0.15 to 0.20 grains per cu. ft. is sufficiently clean for boilers and stoves and it has been reported that dirty stoves can be cleaned by the use of such gas. For gas engines, however, one-tenth of this amount is all that is permissible.

2 In a number of cases it has been found that one centrifugal dust catcher removes 85 % of the dust which may be caught by the dry method and a second one is practically a waste of money.

3 Most of the secondary cleaning in the United States is done by a series of different types of washers, although at Steelton the secondary stage has been reduced to a single piece of apparatus. It is the secondary or stationary wet scrubber stage that I wish to mention especially.

4 I believe the first blast furnace gas engine to be operated in America was that at Steelton, a Westinghouse vertical engine, using a coke-filled scrubber to clean the gas. The enormous quantity of dirt promptly filled the scrubber, and the difficulties with engine

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[1] Experimental Engineer, Pennsylvania Steel Co., Steelton, Pa.

operation were similar to those experienced at Lackawanna, due to lack of cleaning.

5 The most recent development of the scrubber may be said to be the Zschocke washer, built originally in Germany and, with modifications, much used in the United States. The primary washers described by Mr. Freyn are of this type. It is a type of scrubber in which an attempt is made to limit by the mechanical design the exact relation between the voids of the scrubber and the solid matter, consequently fixing the relation between the water contact surface and the area of the gas passages.

6 It would seem, however, to be a waste of money to build a tower of a certain size and then partially fill it with solid materials, thereby increasing the velocity of the gas through the tower and decreasing the time allowed for cleaning. If it were possible to present the same water contact surface and accomplish the same mixture of gas and water, and still maintain the full area of the tower, or very nearly so, it would be an advantage. This result is obtained by the sprinkling type of tower in which the grids or hurdles are eliminated and the water is caused to descend through the tower in drops. Of prime importance in this type of tower, however, is the uniform distribution of water and the breaking up of the water into sufficiently small particles. In case a particle of dust be brought into contact with a film of water, as in the Zschocke washer, if the dust particle is sufficiently small it may not be able to pierce the water film, due to the resistance of the surface tension of the water. Consequently, if the size of the drops of water be reduced to a point where they become much smaller than the size of the dust particles, the water particles will envelop the dust particles, weight them down and carry them downward by entraining acton, depending on the increased density of the dust particles with the film of water. The question of attaining this theoretical condition has been a difficult one.

7 The Mullen washer and the Moyer washer, which is a modification of the Mullen washer, are known as impinging types of washers. The gas comes into the top of the chamber, passes down through tubes, impinges upon a water surface, and then goes off in a reverse direction. The efficiency of such an apparatus as a gas cleaner, so far as dust is concerned, has been found to be very good, but the gas is not cooled in its passage through this scrubber, and frequently leaves at a temperature of about 300 deg. Gas at 300 deg. can contain about two hundred and sixty grains of water per cubic foot, and gas at the ordinary atmospheric temperature can contain only five

to seven grains per cubic foot, depending on the temperature. When this entrained moisture is carried into the stoves and boilers, it must be evaporated except for that which has been condensed on the way over. The loss is very material, and I know of one plant using a changed form of the Mullen washer that has abandoned its use in the original form because of the increase in the moisture content of the gas. If it were possible to cool the gas after the impinging action, it would be a very efficient type of scrubber.

8 The plant of the Penna. Steel Co. consists of a single type of apparatus for each of the three stages. For the first stage a centrifugal dust catcher is used; for the second, two similar sprinkling-type wet scrubbers; for the third, two similar rotary wet scrubbers. The plan of the cleaning plant is shown in Fig. 1. The gas travels from *A*, the downcomer from No. 3 furnace, into *B*, the centrifugal dry dust catcher, out through gas mains *C* and *D* to inlet pipes *E* and *G* of wet scrubbers Nos. 1 and 2 respectively. Leaving these scrubbing towers the gas may be taken off at one side through *H* to the rotary scrubbers or through *F* and *L* to the gas main *M* supplying stoves and boilers. An alternative course is provided from *E* through wet scrubber No. 1, out at *F*, thence to *G*, and through scrubber No. 2 to *H* or to *L*. The wet scrubbing plant may be by-passed to get gas to the stoves and boilers. The valves *V* are all water sealed. It is seen that the wet scrubbers may be operated in parallel (as originally intended) or in series if found necessary.

9 The scrubbing towers are each 25 ft. in diameter by 60 ft. high. The elevation is shown in Fig. 2. Gas enters through the brick-lined flue *A*, impinges upon the water seal surface *B*, passes up through the tower *C*, meeting there the rain descending from the distributor above and leaves at *D* or at *E*. The gas flues are brick lined as far as the towers, and the dry dust-catcher is brick lined except for some cast-iron wearing plates, in order that the gas may arrive at the tower as hot as possible. The hot gas immediately upon impinging upon the water seal gives up a portion of its heat in evaporating water which is quickly condensed by the rain from above. When this evaporated water is condensed from a gas to a liquid it necessarily passes through a state when the water particles are smaller than the dust particles carried by the gas and will attach themselves to the dust particles in condensing, thoroughly wetting them and weighing them down. In this condition they are readily washed out by the rain through which they are compelled to pass in ascending the tower. The distributor used in this tower for distributing water (Fig. 3) has been the

subject of a great deal of study and experimentation, and consists of a steel shaft *A*, extending through the top of the tower, with a bearing *F* on the outside, carrying at its lower end a wheel, the frame

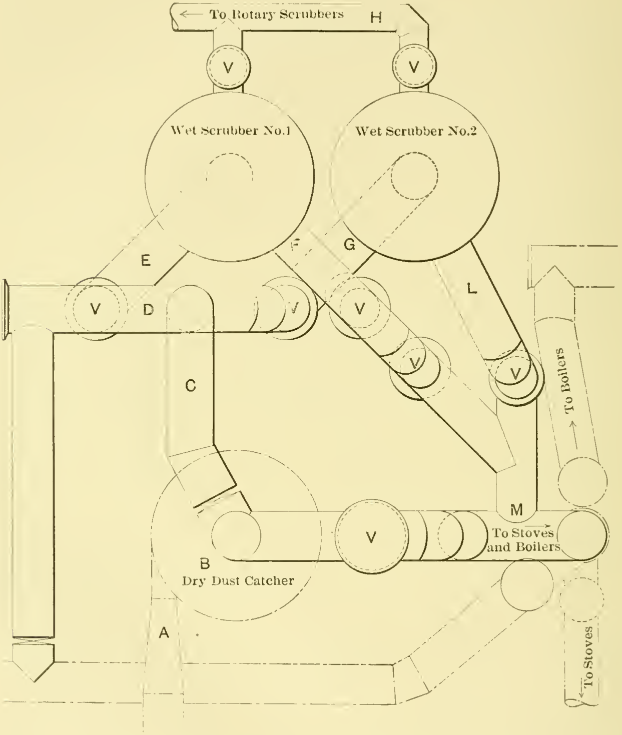

FIG. 1 PRELIMINARY GAS CLEANING PLANT

being of pipe work, and on the horizontal top surface *C* a screen of about one quarter inch mesh wire. This screen is rotated, water is brought in at the top through the nozzles *D*, bent at an angle of 90 deg., so that the water strikes the screen tangentially, at an angle to a radius, and opposite to the direction of rotation. This arrangement gives a practically uniform distribution.

10 Some of the advantages of this distributor are that there is no resistance to the passage of the gas from the bottom of the tower to the top, there being no obstruction whatever. It is possible by means of manholes to get at this single screen and clean it in case of obstruction. The water nozzles are all connected to a manifold on top of the tower and are readily removable from the outside for cleaning in case of clogging. The water is carried to this manifold at about one pound pressure, just enough to lift it to the top of the tower. When the gas leaves the tower it is hoped to have it sufficiently clean to go to the stoves and boilers. It has been found in one scrubber tower that was built with a distributor, not of this type, but giving practical

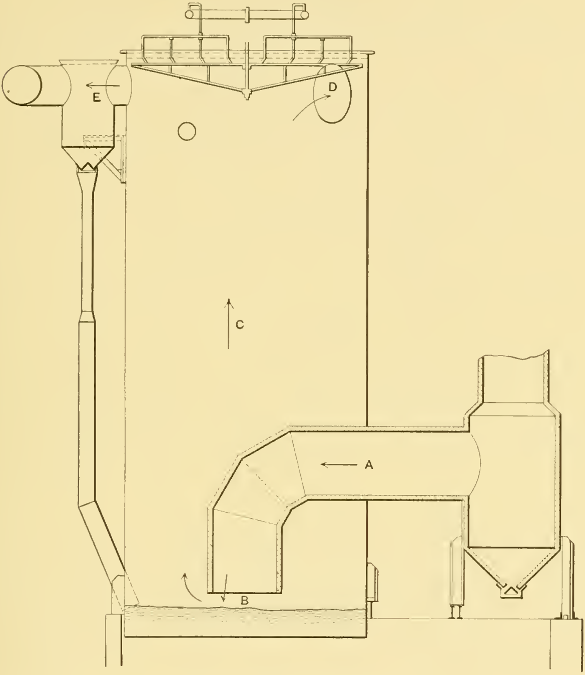

FIG. 2 SCRUBBING TOWERS

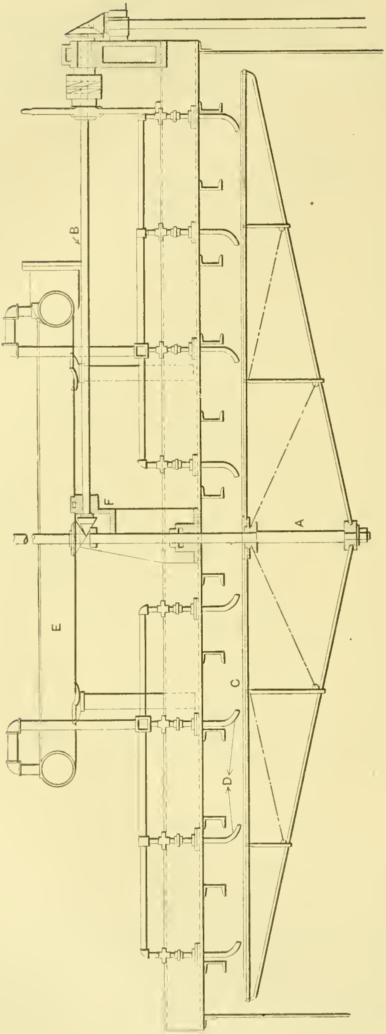

Fig. 3 Water Distributor in Scrubbing Tower

uniform distribution, that the gas was sufficiently clean for stoves and boilers in one operation, and we feel that we will be able to do the same thing. There is no resistance to the passage of the gas through the scrubber, and it should not be necessary to put in fans to force the gas to the stoves and boilers.

11 The gas from *H* goes to the secondary washers. For this operation I think there is no doubt that the Theisen washer will solve the problem very successfully.

H. G. H. TARR.[1] During a recent trip to Germany I visited some of the larger iron works and was interested in observing the differences that exists in their method of preliminary gas cleaning. It is probable that this arises from the difference in ores and materials treated, as much as from the opinions of engineers as to the best methods. For final cleaning, however, the Theisen washer is quite extensively used. I was told in England, as well as in Germany, that gas was being delivered to the engines through these washers in a higher state of purity than existed in the air, and this seems to have been born out by experiences in this country. There is a very great probability that the time is not far distant when the air will be washed, as well as the gas.

2 This leads to the thought that this method may be adopted for cleaning the air entering churches, hospitals, theaters and wherever there are large assemblies of people.

EDWARD RATHBUN. Probably the most serious thing we have to consider as engine builders regarding producer gas engines is the question of gas cleaning, or to be exact, the cylinder wear, and in conjunction with the valuable information contained in Mr. Freyn's paper, I would very much like to see some data regarding the relative wear of the engine cylinders as the various cleaning processes were developed.

JESSE M. SMITH. When I was building blast furnaces in Central Ohio, prior to 1880, we were smelting native ore with raw bituminous coal containing a tremendous amount of dust, which not only stopped up the flues but also the space below the boilers and in the ovens. To remove this difficulty we discharged the dust vertically downward from the blast furnaces into a cylindrical chamber 12 ft. in diameter and water-sealed at the bottom. This chamber was several times larger than the down-comer. The gas ladened with dust came down against the water and the major part of the dust was caught, to be removed through the water seal. This apparatus worked admirably and after its installation we were not troubled with dust in flues, under the boilers or in the stoves.

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[1] R. D. Wood and Co. Camden, N. J.

2 I have found in this connection, as well as in the cyclone dust catchers used in flour mills, where the centrifugal motion is used, that final separation of fine dust from air or gas must take place, as Mr. Stott has said, by sudden reduction of the velocity so that the gas has an opportunity to deposit its heavy portions on a surface that will catch and hold them.

Charles Whiting Baker. To obtain clean gas for engines, the use of a water spray results in great reduction of temperature. It is also possible that in modern practice where very fine ores are used, it may be necessary to employ water for cleaning the gas to be used under stoves and furnaces. The 300 to 400 deg. of heat lost in the cleaning process would be worth while saving if we could discover some means of dry cleaning the gas. It is entirely possible that by using the dynamic process or the type of cleaning used in flour mills the gas might be dry cleaned and delivered to the stoves and furnaces at its original temperature.

E. P. Coleman. As stated in Appendix No. 5, contributed by Mr. Bacon, certain liberties were taken in the design of the 60-in. Venturi meter, in that the junction between elements of the upstream cone and the cylindrical throat is angular, not being formed by means of an easy curve as is usual. By referring to Fig. 23*b*, it will be further observed that the distance from this angular junction to the $\frac{3}{16}$-in. holes communicating with the angular pressure-chamber is relatively small. The coefficient of 0.91 for this meter as determined by means of the gas-holder, is in all probability correct, but it is believed that, if the junction had been rounded, or the $\frac{3}{16}$-in. holes situated farther down stream from the angular junction, or both, that the coefficient would have been greater. In addition to the probable eddy loss noted by Mr. Bacon, it seems probable that a contraction of the stream also occurs at a point in the stream opposite these holes. Each of these conditions, if existing, will lower the coefficient. By rounding the junction the eddy loss is reduced; and by locating the pressure holes at a section of the throat which is filled by the stream, the pressure difference should more closely approximate the ideal.

2 Considering the extraordinary facilities provided by the 100,000-cu. ft. gas-holder for accurately determining such coefficients, it seems unfortunate that commercial reasons were allowed to affect the design. The writer believes that a Venturi meter of 6-in. diameter or more, and of the best design and construction, will show a coefficient greater than 99% with usual gas velocities.

A. Bement. While the successful outcome of the plant described by Mr. Freyn is cause for congratulation, it is probably correct to say that if the application of the gas engine in connection with blast furnaces had been delayed much longer it might have found very strong competition in the gas-fired boiler supplying steam to turbines direct-connected to electric generators and to blast furnace blowing engines.

2 Relative to safety devices, the writer believes their use in all possible cases to be desirable, and is inclined to the belief that the feeling of opposition to them is based upon the assumption that they will be expected to take the place of manual supervision. Where safety devices have been successfully employed with delicate electrical apparatus marked success has been secured. It was necessary, however, that the apparatus be watched and kept in order. Its use is not for the purpose of taking the place of the watchfulness of the men, but as supplementing it.

3 Contrary to expectation when the use of furnace gas in engines was proposed in Europe, it has been found that the removal of dust from the gas is a matter of the greatest importance This is especially true in this country because of the finer ore and harder driving of furnaces. In this connection dry air blast promises to effect a marked reduction in the amount of dust carried by the gas, as its use appears to result in very much more even working of furnaces and a very marked reduction in the number of slips.

W. E. Snyder. This paper is without doubt the best description and operating record of a blast furnace power plant that has ever been published, and great credit is certainly due the broad-minded officials of the company operating this plant for their action in making the data available. Great credit is also due to Mr. Freyn for the very complete records which he kept and for their very clear and thorough presentation. A discussion of this paper is possible only by considering the subject of the paper as a topic upon which others may add their experiences. I will discuss the paper in this way, giving some notes relative to European operating experiences and comparisons with American conditions.

2 During the early part of 1908 I had the opportunity of investigating gas engine practice in almost all of the countries of Europe in which gas engines are used. During this investigation I visited 29 different plants on the Continent, and saw in round numbers 365,000 horse power in operation. I also visited eight different works where large gas engines are built. At all of these plants I had opportunities for discussing their experiences with different engineers and operating men in charge. Although this was about two years ago, the development of gas engines and gas cleaning had at that time proceeded far enough to evolve certain standards of apparatus and methods of operation which have not changed materially since then.

3 The country which has made the most rapid strides in the development and use of large gas engines driven by blast furnace and coke oven gas is Germany. The first small gas engine to use blast furnace gas in Germany was put in operation in October 1895. In the early part of 1906 Dr. Reinhardt, of the Schüchterman & Kramer Works, estimated that there were then under construction or erection or in operation in German steel works 349 large gas engines, aggregating about 385,000 horse power, and in German collieries 35 gas engines, aggregating 30,300 horse power, a total of nearly 400 large gas engines. By far the larger proportion of these were installed during the period from 1902 to 1906. Other countries made contemporaneous progress, though not on such a large scale.

4 The effect of this rapid development in an entirely new field was that the early experience of many of the gas engine stations was one of continued and varied troubles. These troubles, while exasperating to the engineers in charge of operations and discouraging to the financial managers, constituted the experiences from which were evolved the very satisfactory European installations of the present day and the large installations in this country. European experience during this period of development, while very interesting, is of no importance compared with operating results from the more recent large gas engine installations, such as are given in Mr. Freyn's paper.

5 A feature of the use of large gas engines in Europe is the great confidence reposed in them by both builders and users. Gas engines were put in to work under the greatest variety of conditions, not alone for blowing blast furnaces and for electric driving, but for the

direct driving of mills, of which I saw several installations, including merchant and small bar mills, rod mills and sheet mills. One steel plant was equipped with a large gas blowing engine for the converters. At two works some of the gas engines were so constructed that they served for driving either blowing cylinders or electric generators as might be required. At other works a mixture of coke oven and blast furnace gas was used, or even producer gas and blast furnace gas. In fact, there seemed to be no hesitation whatever in depending on the gas engine to operate under as widely varied conditions as the steam engine, and this confidence in what could be done with the gas engine was usually justified by the results. Sometimes, of course, there was a great deal of trouble and expense involved, but the work went on without change in general plan.

6 The type of engine which seems to be the general favorite in Europe is the same type that has been adopted for almost all of the important installations in this country. This is the four-stroke cycle, either single or double tandem. There have been long and learned discussions among the technical men of Germany on the relative merits of the two-stroke cycle and the four-stroke cycle engines, but the type which has predominated was not determined by these academic discussions. It was determined by the engineers who were responsible for operation and results.

7 Emphasis is everywhere laid on the necessity of good technical supervision over gas-engine power stations. As the prime requisite for good operating results, a good gas engine is specified; for the second requirement, efficient technical supervision is provided, coupled with records of running conditions somewhat similar to those presented in Mr. Freyn's paper, though not so complete.

8 The primary necessity for a good engine to begin with seems so self-evident, but it indicates the responsibility that is everywhere placed upon the engine builder. The greatest troubles which develop are due to fire-cracking of the cylinders and pistons. The design of those parts is now much better understood than at first, with the consequent prevention of most of these difficulties. A very common size of cylinder in the newer installations is 1100 m.m. (43.3 in.) diameter and 1300 m.m. (51.3 in.) stroke. Each cylinder of this size at 95 revolutions develops about 1000 horse power, which requires a m.e.p. of 56 lb. Cylinders of this size and smaller were complete of one casting without a bushing. Since the time of my visit, however, cylinders have been designed and constructed to develop 1300 horse power each, approximately 52 in. in diameter by 56-in. stroke. There

have also been developed cylinders made of two or more castings fastened together by strong and tight joints. This is to avoid the difficulties due to shrinkage stresses and to the stresses in the casting caused by the difference in temperature between the inner and outer walls. Hard cast-iron bushings are also used, and some engineers are considering steel cylinders, if indeed they have not already been constructed.

9 These most recent developments in the construction of cylinders are very radical changes from what was the practice among leading builders but two years ago. Whether these changes are due in part to American experience or not it is not possible to say, but evidently the design of multicasting cylinders with bushings is due both in this country and in Europe to a common cause, the effort to increase the reliability of the cylinder, which result is certainly accomplished.

10 The operation of gas-engine driven generators in parallel at 25 cycles was common, as was also their operation with steam-engine driven units in parallel. The operation in parallel of two or more plants, gas or steam driven, but located at different places, was also practiced. Many of the newer units installed do not have flywheels, the entire flywheel effect being produced by the rotating part of the generator. The yoke frame is usually used, i.e., the main frame is designed with a bearing on each side of the crank. The various details, such as valve gears, regulating mechanism, igniters, etc., were in various stages of improvement, the object everywhere being to simplify and at the same time to retain or improve the efficiency and reliability of operation.

11 The newer installations in Germany are splendid examples of engineering accomplishment. This is true not alone of the gas engines but also of the electrical apparatus, buildings and auxiliary equipment as well. Every detail seems to have been given attention, and where previous experience, or engineering foresight could serve as a guide, provision has been made for convenient and economical operation. One of the stipulations in contracts for gas engines now being installed is that after all adjustments have been made and the engine put into regular service it must run for four weeks continuously without stop or slow-down, and there is no difficulty whatever in fulfilling this condition.

12 With regard to the cleaning of blast furnace gas, there was almost every conceivable combination of dry dust catchers, vertical washers, and rotating washer devices, such as fans, Theisen machines, etc. Many works do not have Theisen machines in use for fine clean-

ing the gas, but use two or three fans in series. However, I did not hear any unfavorable criticism of the Theisen apparatus from anyone. The opinion was general that it was the most efficient method of fine cleaning the gas that had then been devised. Considering the gas cleaning proposition as a whole, from the furnace to the engine, I did not see any installation superior to the best installations in this country, and I doubt if their equal exists in any of the European works. There is a reason for this in that the importance of cleaning gas thoroughly was fully realized in this country when gas engines were first considered, while in Europe it was at first thought that cleaning was not of much importance. The extended European experience with different systems and apparatus for cleaning gas for gas engines was available for the American steel works engineer when he first took this matter up, while there was no such experience available for the European engineer and all of the apparatus required had to be developed. There is a greater difference between the best gas cleaning plants in this country and in Europe than there is between the gas-engine power stations, or more particularly, the gas engines themselves. There is a strong probability that the reason for this is that here the steel works engineer, whether consciously or unconsciously, made more use of gas cleaning experience in Europe than was made of European gas-engine experience by the American designer. It is a fact that there has been practically no trouble here in the thorough cleaning of gas for engines in the principal installations, while there has been a great deal of trouble with the gas engines themselves in these same installations. Most of these difficulties have now been overcome, but many of them could have been avoided if the American designer had profited by the fund of European experience which was available when he first began his work.

13 The following may be given as interesting items of comparative data with reference to gas cleaning: Dr. K. Reinhardt found that the water consumption of Theisen machines varied in different plants from 22 to 60 gallons per 1000 cu. ft. of gas cleaned. The plant described by Mr. Freyn used an average of 19.4 gal. per 1000 cu. ft. Dr. Reinhardt also determined the horse power per 1000 cu. ft. of gas cleaned by Theisen machine to vary from 0.17 to 0.37. Calculation from the data given by Mr. Freyn shows that the Theisen alone required 0.20 h.p. per 1000 cu. ft. of gas. German practice had come to regard 0.02 grams of dust per cubic meter, equivalent to 0.009 grains per cu. ft., as a standard for cleanliness of the gas. This was a compromise between what was thought possible for a gas cleaning

plant and what was desirable for gas engines. The average dust contained in fine gas for the year as given by Mr. Freyn's paper is 0.0058 grains per cu. ft. which is about 65 per cent of the approximate maximum fixed by German practice as standard.

14 The velocity of the gas allowed in the different mains and pipes as given by an experienced engineer was as follows: In large gas mains from 15 to 20 ft. per sec.; in smaller pipes connecting the different parts of the gas cleaning apparatus, 33 ft. per sec.; in branch pipes going to engines, 66 ft. per sec.; in valves and gas passages of the engines 130 ft. per sec.

15 In some of the plants no charge was made to the power station for gas used. At many of the largest and most modern installations, however, a charge was made for the gas. This charge was determined by measuring approximately the quantity of gas used per month and calculating from its average composition the heating value of the gas per cubic meter. This was then evaluated by comparing with the heating value of standard coal used at the plant. In a few instances gas calorimeters were in use, but all instruments for measuring or testing gas were in process of rapid evolution and no method had general acceptance, either in the engineering or accounting problems involved in valuing the gas and accounting for it.

16 Venturi meters were not used in any plant for measuring gas. The usual method of determining the quantity of gas was to use an instrument based on the Pitot tube principle, the tube being located at a point in the cross section of a straight run of pipe which has been determined by test to be approximately that of average gas velocity. The instrument was nearly always of the continuous recording type, with charts graduated to record gas velocity.

17 For lubricating the gas engine cylinders, the largest and heaviest types of lubrication that I have ever seen were in use. These lubricators were of very massive construction, and were frequently placed on the floor beside the gas engine, looking not unlike small vertical engines. They were connected to a number of oil pipes, which supplied lubricant to the cylinders, exhaust valves and rod packing. The cylinders were usually fitted with from four to six oil pipe connections, these being placed where, in the judgment of the designer, they would do the most good. It was not the practice to attempt to discharge oil in the cylinder at any particular point in the stroke. The method of driving the lubricator prevented this.

18 There was great variation in the kind of oil used, but the concensus of opinion agreed that the cylinder oil should be of light body,

containing a minimum of heavy carbonaceous matter. The only test I could find being applied to oil for gas engines was that the smaller the residue when the oil was vaporized the more suitable it is for gas engines, provided that it has the general characteristics of good lubricating oil. At some plants they were using oil of the same kind in the cylinders as was used in the bearings and pins of the engine.

19 At many of the large installations great care is taken to provide for the safety of the men in charge of the gas engines and gas cleaning. Various kinds of safety apparatus are placed where they will be quickly available in case of accident, and the men are trained in the use of this apparatus. There are also rules in force which are intended to promote safety conditions. One of these provided that no less than two men shall work together, the presumption being that in this case there will always be one to raise the alarm in case a man is overcome by gas. Another rule provided for the proper ventilation of cellars and the prevention of gas pockets about the foundation or building. As a result of these precautions accidents due to the effects of gas are said to be very infrequent.

20 During the past two or three years very rapid progress has been made in this country in the improvement of details, both in the design and construction of engines and in their operation. Some American engineers have done splendid work in designing large gas engines to meet American conditions. One of the most important improvements is the cylinder made of two or three different castings, fitted with a hard cast-iron bushing. The use of steel castings for cylinders is also an important development. It is not intended to imply that these features of cylinder construction are distinctively American practice, but American conditions and designers are no doubt largely responsible, since this form of construction developed very soon after the manufacture of large gas engines began in this country.

21 Another improvement in detail that is distinctively American is in the method of lubricating the cylinders. It is now very general practice here to have two oil pipes for each end of cylinder, each pair being located at the top of the cylinder, one a short distance on each side of the center line. The oil pump is connected in such a way that the oil is discharged at the beginning of each suction stroke where the piston covers the oil holes. The lubricators used for delivering the oil to the cylinders are much smaller and less cumbersome than those in use in foreign plants and seem to be just as satisfactory. A system of forced-feed lubrication for all bearings, pins, etc. has been

developed and is now in successful operation. This is of special importance in that it contributes towards higher piston speed, thereby reducing the first cost per unit of capacity and the floor space required.

22 The governing mechanism has also been improved to such a degree that all principal builders are ready to guarantee successful parallel operation of 60-cycle a. c. generators. This is also an improvement, but it came too late to influence the characteristics of the principal installations now in operation. At these plants the 25-cycle system was selected of necessity and must now be adhered to because it is too thoroughly established to permit of change.

23 Still another important improvement in detail which is distinctively American is the kind of cylinder used in large gas blowing engines. The blowing cylinders I saw on most of the gas engines of Europe, I consider the poorest part of the whole installation. A large proportion of these cylinders have the old type mushroom poppet valves for both inlet and discharge. While these may have been fairly well suited to the low blast pressures carried at most of the European plants, they are wholly unsuited to American conditions and to use them on gas engines here would be going back to the practice of 15 or 20 years ago. In order to get the most efficient results from a gas blowing engine, mechanically operated valves are necessary. This fact has been fully appreciated by American designers and some splendid examples of cylinders fitted with this type of valve have been produced. The equal of these American blowing cylinders with mechanically controlled valves is not made anywhere in the world and their use facilitates higher rotative speeds, which in turn reduces unit first cost and floor space. Speed control for blowing engines is a feature in which the best American engines equal the best used in Europe at present.

24 Gas cleaning, the construction of gas engines, and their operation are all now well understood in this country. The engineering problems involved are appreciated, even though they are not all solved. The commercial features involved are not of the most importance because a gas engine installation will in this country, for years to come, be a very expensive installation per unit of capacity. The price of fuel at all blast furnace plants in this country is low compared with what it is in Europe. The manager, in considering gas engines, must face the American aspect of high plant cost and low fuel cost. In this connection any improvement, such as forced-feed lubrication mechanically-controlled air valves, etc. which facilitates higher piston speeds, is an improvement which makes the large gas engine

more generally available for consideration in American plants. What is required is to increase the earning capacity of any given unit or installation. High load factor at nearly continuous operating conditions is one of the principal requirements for gas engine plants. It will therefore be seen that while a collection of data as given in Mr. Freyn's paper is of great interest from an engineering standpoint, it is also of particular importance in its bearing on the commercial use of gas engines, i.e., it is a record of the efficiency or output of each principal part of the power plant, so that it is always known whether or not the installation is maintaining the best operating efficiency consistent with the operation of the works which it serves.

THE AUTHOR. As Mr. Maccoun states, all large gas engines built in this country are of the side crank type, as this design was insisted upon by the steel works' engineers, and it cannot be denied that the side crank design proved to be very satisfactory and has many advantages over the center crank construction, but it should not be overlooked that it makes American gas engines considerably heavier and more expensive than European engines, which are without exception built with center cranks.

2 Regarding the question of governing gas engines, the governing by constant mixture is decidedly favored by American engine builders, and it appears that this system gives more satisfactory results in our practice than the so-called constant-compression-stratification method of governing.

3 I cannot agree with Mr. Maccoun that it is of such great importance to use some particular brand of cylinder oil for lubricating gas-engine cylinders. At the plant under discussion very excellent results are being obtained by the use of standard gas engine oil, which has about the following characteristics:

Viscosity Tagliabue	Flash point deg. fahr.	Fire point deg. fahr.	Spec. Gravity
79.1	395	456	0.912

This oil is considerably less expensive than the special heavy oils suggested by Mr. Maccoun, whereas the quantity consumed is not very much greater, so that the net result is a material economy in the cost of lubrication. Frequent cylinder examinations have proved that the use of standard gas engine oil does not entail carbon deposits, since the oil is burned up completely, not leaving any residue in the counterbore nor under the piston rings. This, in my experience, cannot be said of the high-priced oils which, in order to obtain the high flash and fire points, must necessarily contain heavy hydro-carbons.

4 In regard to the amount of power obtainable from blast furnace gas, I think that the figure of 25 h.p. per ton of pig iron produced in 24 hours is pretty generally admitted to be a reliable basis for general calculations of the available power. It is true that this figure does not apply in every particular instance, and especially not in cases of plants having less than two or three blast furnaces. There are plants in existence, however, where practically no coal is burned under the boilers, and where all power requirements for the mills are being supplied by the excess gas from the blast furnaces. The Gary works of the Illinois Steel Company exemplify this statement.

5 Mr. Maccoun is perfectly correct in maintaining that the gas engine is not the universal panacea for the needs of a blast furnace plant. In isolated plants, for instance, where a large proportion of the gas produced by the furnaces must go to waste simply because there is no field for its utilization, and where the gas is therefore of no value, the installation of costly gas engines may be uneconomical and undesirable. In other plants there may be old steam engines in operation which are running so satisfactorily, though not economically, that they may render good service for years to come. In such cases it would be a waste of money to discard these engines and to replace them by gas engines, since the low-pressure steam turbine is available to improve materially the thermal efficiency of such plants.

6 In connection with the question which has aroused most of the discussion, namely the preliminary cleaning of blast furnace gas, it seems to be the unanimous opinion, brought out by Messrs. Morgan and Uehling, that it is obsolete practice to use raw blast furnace gas for any purposes about a blast furnace plant. It is generally recognized today that the gas for hot blast stoves and boilers should be cleaned to prevent the deleterious effect of the flue dust on the checker brickwork in the hot blast stoves and on the boiler flues. Opinions, however, are divided as to the degree to which blast furnace gas for these purposes should be cleaned, as well as to how this cleaning should be performed. According to the information obtainable on the subject at present, it does not seem possible to clean blast furnace gas by a dry process alone to such a degree of cleanliness as is claimed to be desirable in some of the discussions.

7 While it would seem consistent to assume that the benefit derived should increase proportionally with the degree of cleanliness of the gas, this is not so, since the ultimate economy is not only depen-

dent upon the increased life of the checker work in the stoves, the high heats obtainable and the reduced labor of cleaning stoves and boiler flues, but also to a very great extent upon the cost of installation, operation and maintenance of a gas-washing plant.

8 The discussion of this phase of the problem of gas cleaning bears out the general conviction that if blast furnace gas could be sufficiently cleaned by a dry process only, such a cleaning plant could be installed, operated and maintained at a much lower cost than if wet scrubbers, pumps, fans, etc., were necessary to accomplish the purpose in view. My opinion is that dry cleaning of the blast furnace gas can be most effectively accomplished in an apparatus fulfilling the following three conditions:—

a Reduction of temperature of the gas
b Sudden change of direction
c Sudden reduction of velocity

As explained in the body of the paper, a reduction of temperature of the gas can be accomplished without expense by the use of unlined gas mains. Too much importance should not be attached to the advantage of preserving the sensible heat of the gas, and calculations at the plant under discussion have shown that the loss due to reduction to atmospheric temperature does not exceed 8%. On the other hand any reduction in temperature of the gas is coincident with a corresponding reduction of moisture, a very important factor in the economical burning of the gas in stoves and under boilers.

9 The design of any effective dry cleaner should make it impossible for the dust to be stirred up after it is once deposited and this implies provision for carrying off the separated flue dust in such a manner that it is protected as much as possible from the effect of slips and the tendency of the gas current to entrain the dust particles. Any dry cleaners based on the action of centrifugal force are necessarily much more effective than the old type dust catchers, wherein the separation of the dust occurred merely by the reduction of velocity in voluminous chambers. Granting the above requirements for an effective dry cleaner, the horizontal dust separator described by Mr. Morgan must prove to be a very efficient dry cleaner.

10 At the plant under discussion a great deal of experimenting on a large scale was done in connection with this problem. As explained in the body of the paper, very voluminous dry dust catchers of the tangential type were installed at all furnaces, but it was found that the efficiency was comparatively low.

11 A new development in the dry cleaning of gas is now being

perfected at this plant, and it promises to solve the problem in a very simple, inexpensive and effective manner. This is the Brassert-Witting dry dust cleaner, letters patents for which are now pending. This dry cleaner combines in one apparatus the above named principles of successful dry cleaning, since it is unlined, makes use of centrifugal force, positive friction, reversal of direction and sudden expansion of the gas while protecting channels take the dust out of the path of the gases. These dust catchers are inexpensive and the operating cost is practically nothing, as they discharge the dust directly into railroad cars. The advantage of this system, aside from the low cost, is the fact that all the dust is recovered in a dry condition, doing away with the nuisance of sediment in sewers, river, etc. It has been shown in actual practice that one of these ten foot Brassert-Witting dry cleaners will take out about twice as much dust as a large forty foot dry dust catcher of the system preceding it, and with three of these cleaners in series, it is possible to obtain a cleanliness of less than one-half grain of dust per cubic foot.

12 With reference to Mr. S. K. Varnes' contribution on the question of wet gas cleaning, it is unquestionably true that this object can be satisfactorily accomplished in wet scrubbers other than the one described in the paper. Whether, however, such wet cleaners are more effective and cheaper in operation is yet to be proved. The four wet scrubbers in the plant under discussion, now operating in parallel, show an efficiency of over 90% for the last three months. The reduction of gas pressure to which Mr. Varnes refers is of no consequence since it does not exceed one inch of water column.

13 I cannot imagine a better distribution of water than that obtained in a tower filled with hurdles, since the water falling from hurdle to hurdle on its way from the top to the bottom of the wet scrubber is broken up again and again into a very fine mist so that practically every particle of gas must come into thorough contact with the water. I do not believe that the dust particles have to pierce a water film in order to be removed from the gas, but that the action which takes place in any type of scrubber consists in the wetting and weighing down of the dust particles by microscopical water drops in suspension.

14 The influence which impurities in the gas have on the cylinder wear can practically be disregarded if the engine gas is thoroughly cleaned in a modern cleaning plant. Conditions have changed materially in this respect in the last eight or ten years. Before adequate gas cleaning plants were in use the amount of impurities carried into the

engines was so great that the dust and the lubricating oil formed a grinding material which caused the cylinders to wear out in a distressingly short time. Cylinder wear in modern blast furnace gas engines is not primarily due to the dust, but to the material of the cylinders, piston ring design, lubrication, etc.

15 Mr. Stott mentioned that he has obtained with a combination of reciprocating steam engines and low-pressure steam turbines, a thermal efficiency of over 21%. It is evident that Mr. Stott is referring his thermal efficiency to the total amount of heat contained in the steam at the engine throttle and that he does not take into account the losses occurring by steam transmission between boiler house and engines, nor the efficiency of the boilers themselves and the losses in the boiler house. Inasmuch as in a blast furnace plant the blast furnace gas is the available fuel, which in one case is used directly by combustion in the gas engine cylinders and in the other case indirectly under boilers for raising steam, a fair comparison of the efficiencies of these prime movers can be made only on the basis of the amount of heat units contained in the gas delivered at the gas cleaning plant in the former and at the steam boilers in the latter case. Assuming that the combined losses in boilers and by steam transmission to the engines amounts to 35%, so that the combined efficiency of boilers and steam pipe is 65%, the thermal efficiency of Mr. Stott's installation would not exceed 13.7% compared with about 21% realized with our gas engines.

16 The latter figure, moreover, is not a value obtained by one or a series of individual tests, but is the average of the results obtained in actual commercial operation of the plant during the period of one year; nor is this figure in any way exceptional, as there are gas engine plants in existence abroad where average thermal efficiencies of 25% and more are being realized. There is no reason why with mechanically perfect engines of modern design these figures should not be duplicated and even exceeded in this country.

17 Mr. Coleman's discussion was submitted to Mr. C. J. Bacon, who states that the matter of which Mr. Coleman speaks namely, accounting for losses in the Venturi meter, was not included in the paper as there was no definite information available on the relative losses due to eddy currents, location or pressure holes, imperfect workmanship, etc. Mr. Bacon fully agrees with all that Mr. Coleman says.

18 It is with particular pleasure that I refer to Mr. W. E. Synder's remarkable contribution as one of the most valuable accounts

of European gas-engine practice which has yet appeared in print and it will undoubtedly prove of great interest and value to the profession. Having had experience in both European and American gas-engine practice and having actively witnessed the early development of the blast furnace gas engine here and abroad I feel competent to endorse the views expressed by Mr. Snyder in every particular.

19 In preparing my paper I purposely refrained from broaching the subject of gas engine design and construction; nor did I yield to the temptation of relating my personal experience with gas engine operation here and abroad, well knowing that my reference to these subjects would have brought out a veritable avalanche of discussions on the part of both gas-engine builders and users. In line with this reasoning I do not care to take up point by point Mr. Synder's remarks on the construction of certain gas engine parts, but I wish to elaborate a little on one statement which is in line with the subject matter of my paper.

20 It is an established fact that all gas cleaning plants installed in this country within the last five years have been very successful and practically free from trouble. This is largely, if not exclusively, due to the insight of American steel works managers, who recognized that in view of what had been done in Europe along this line any attempts to solve the problem inadequately by carrying on lengthy and costly experiments would have meant wasting money and retracing again the steps which their European colleagues had taken before. Instead they willingly took advantage of the experience of others and adopted European methods and apparatus, perfecting them to meet their own conditions. It is equally true that many of the difficulties encountered in the operation of our gas engines in this country would have been avoided if this principle of profiting by the experience of others had been more closely adhered to in designing and building American gas engines.

21 It is very gratifying to note the close coincidence of the results obtained in American and European operating practice, especially in regard to the purification of blast furnace gas and the lubrication of gas cylinders.

CRITICAL SPEED CALCULATION

By S. H. Weaver, Published in The Journal for June 1910

ABSTRACT OF PAPER

The motion of a rotating shaft is treated mathematically as vibrations along two axes at right angles to each other. Properties of the equations of vibration are discussed and curves given showing the amplitude of vibrations at different speeds for various shaft loadings, spans and bearing supports. For the points of maximum vibration, the general formulae are reduced to special forms and given in a reference table for convenient use.

DISCUSSION

Henry Hess. In all of the valuable formulae developed by Mr. Weaver the center of support at the journal is assumed as a definite single point. As a matter of fact, machine journals are not definite single points but vary in length from one to five shaft diameters. It is usually assumed that the center of pressure in a journal with a load to one side of the journal is at a point about one-third the length of the journal, or that such a point is at the center of the journal when equal loads are overhung at both sides. As a matter of fact, however, the actual position of the average load is entirely undetermined. It may be at the assumed point, at one end or the other, or at any point between.

2 If a journal is scraped so as to be absolutely parallel and to fit the shaft throughout its entire length, a measurement of the journal and shaft after being used for some time will show that the journal has become bell-mouthed. A similar measurement later will show that the bell-mouth has changed to the other end of the journal. Any measurement taken between these times will show that the journal is bell-mouthed at both ends. A frequent repetition of such measurements will show that the shape of the journal is continually changing. It follows from this that the point of load concentration is also continuously shifting from end to end and back again.

3 It must be manifest that any formula based on the assumption

of a fixed point of support must fail of giving satisfactory results. No doubt this fact explains much of the trouble experienced in designing elements which are to rotate at high speeds.

4 The solution is, theoretically, a very simple one. It is to provide a journal in which the point of support is definitely fixed to agree with the lengths of the load lever arms assumed in the formula. From a practical standpoint this demands that the journal be of zero length, a requirement which is insurmountable so long as plain journals are used. The difficulty ceases, however, as soon as a ball bearing of that type in which a single row of balls carries the load and in which the contact between the balls and races lies in a plane at right angles to the axis of the shaft is resorted to. This concentrates the load at the theoretical point, or plane, of the formula. When it is desired, the greater stiffness which is given the shaft by the support of a long journal can be realized by using two ball bearings of the type referred to, separated by such distance as is desirable. Here again the points or planes at which the load is supported in the journal are definitely fixed and cannot shift.

S. A. Moss. It is not necessary, as stated by Mr. Hess, to know the exact center of support in the bearings. Vibration at a critical speed is not at a single speed, but through a considerable range on either side of the computed critical speed, the extent of the range varying as the speed is increasing or decreasing or as the acceleration is fast or slow. Hence exactness is useless. I have run some machines with ball bearings, and have not noticed any difference in the range of critical speed. Any change in the point of support simply means that the critical speed comes at a very slightly higher point, a few per cent in most instances.

2 At the critical speed there is the synchronous transverse vibration of the shaft, as has been pointed out, and the simple deflection of the center of gravity does not really occur. The shaft is rotating at the same time it is vibrating and if there is any unbalancing, the center of gravity shifts from the inside to the outside during the course of the transverse vibration. In the vicinity of the critical speed, the shaft is going back and forth between the two positions, and finally, beyond the critical speed, the transverse vibration dies out with the center of gravity on the inside.

M. Nusim. Mr. Weaver makes a passing reference to a paper by Professor Morley where a highly important formula for the calculations is critical speeds is published. Using engineering units this formula is as follows:

$$N = 187.7\sqrt{\frac{\Sigma\, Wy}{\Sigma\, Wy^2}}$$

where N is the lowest critical speed in revolutions per minute, W is any of the weights on the shaft measured in pounds, and y is the corresponding static deflection in inches if the shaft were horizontal. ΣWy represents the sum of the products of each load into the corresponding static deflection. ΣWy^2 represents the sum of the products of each load into the square of the corresponding static deflection. The formula is applicable to a shaft of constant or variable diameter with any number of loads and with any number of bearings, and it includes all of the simple cases given by Mr. Weaver. For such cases there is little preference between the two forms. The Morley formula also covers the more complicated cases (with three loads, etc.), which the simple formulae do not treat, but gives the first or lowest critical speed only. It has been given by Dr. C. Chree in a form suitable for comparing with and criticizing Dunkerley's empirical formula for critical speeds,[1] and was published later, in the condensed form given above, by Prof. A. Morley.[2] The formula mentioned is based on a theorem due to Lord Rayleigh, which states that the period of vibration of a shaft is not affected appreciably if we depart materially from the true shape the elastic curve takes during vibration. This theorem is related to the calculation of critical speeds in so far as a knowledge of the elastic curve of the shaft at this speed is sufficient for the calculation of it. The formula is derived by taking the shape of the elastic curve during whirling to be the same as that due to the elastic loads acting on the shaft when it is horizontal and at rest.

2 It should be noted that in the case of uniformly distributed loads the summations under the radical in this formula become integrations. If these integrations are carried out for the four cases of uniformly distributed loads in Mr. Weaver's table it is found that the error involved is a small fraction of one per cent.

3 In the case of a shaft of constant diameter with two loads symmetrically situated (two or more bearings), the formula follows directly without seeking support from Rayleigh's theorem. This is

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[1] Philosophical Magazine Vol. 7, p.542.

[2] Engineering (London), August 1909.

also true for any number of loads so situated that the deflection under each load is the same

4 It is also easy to see that the formula covers the case of a shaft of constant or variable diameter with a single load. In applying the formula to shafts having more than one span (three bearings or two bearings with overhanging load), it should be seen that the elastic curve has zero deflection at the bearings only, for the reason that at the first critical speed, nodes can only exist at the bearings. On account of this it will in general be necessary to consider the loads on the two spans of a two-bearing machine as acting in opposite directions and find the shaft deflection at the loads under this condition. For all cases other than the ones mentioned above, the formula is not exact, but is only a close approximation. Numerical comparisons made in a number of particular cases with the exact formulae for two loads showed very close agreement. As already stated, the formula applies to a shaft with any number of loads. For such cases it was compared with a laborious method of successive approximations given by Stodola,[1] for each of which the agreement was very satisfactory.

The Author. English writers have considered this subjectas a vibration produced by an external disturbance. Their mathematical work has consisted in calculating the natural period ofvibration. Then the shaft can absorb the energy from a synchronous disturbance such as the lash of the belt, the throb of the engine or other driving mechanism and increase the amplitude of the vibration. Dr. Chree pointed out that the centrifugal force arising from a displacement is opposed to the elastic force or the "righting" force of the natural vibration, so that the frequency of vibration is decreased; and that at the critical speed the frequency is zero when the centrifugal force neutralizes the elastic force and there is nothing to restore the original shape.

2 German writers have considered the phenomena as caused by a disturbing force in the system itself, the centrifugal force of the center of gravity of the mass when not exactly coinciding with the center of the shaft, which is always the case in practice.

3 Mathematically, the last supposition has the advantage of showing the amplitude of vibration at speeds other than the critical value, particularly for two loads on the same shaft which show a minimum vibrating speed between two critical speeds.

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[1] Stodola's Die Dampfturbinen, 3rd edition, 1905, p. 192.

GENERAL NOTES

INTERNATIONAL RAILWAY CONGRESS

At the opening of the International Railway Congress at the Casino in the city of Berne, Switzerland, the American attendance was much larger than at any other previous congress, excepting that held at Washington in 1905. The Congress was formally opened with an address of welcome in behalf of the Swiss government by the federal counsellor and honorary president of the Congress, M. Forrer, chief of the Department of Post and Railways. He was followed by M. Dubois of Belgium, president of the Congress, who traced briefly the history of the Congress and outlined the work of the present session. The subjects under discussion were, Railways and Waterways, Motor Cars for Passenger Service, Rail Joints, Reinforcement of Permanent Bridges in View of Increased Weight and Speed of Trains, Light Railways and Service by Automobiles and Passenger Tickets.

Six reports on the subject of steel for freight and passenger cars were given at the meeting of Section 2. A long report was presented by Mr. D. F. Crawford, Mem.Am.Soc.M.E., of the Pennsylvania Railroad Company. The greater part of the report deals with freight car construction, and Mr. Crawford pointed out that since 1897 there has been a rapid development in the use of steel for both the parts of freight cars and the entire construction with the result that a great industry had been created.

Among other American delegates present were Mr. F. William Mahl and William R. Webster, both members of the Society. The Congress closed July 14.

AMERICAN PEAT SOCIETY

The American Peat Society held its fourth annual meeting in Ottowa, Canada, July 25–27, 1910, with an interesting program which included the inspection of the fuel-testing plant operated by the Canadian government at Ottowa, which is equipped for testing peat for fuel purposes. Two sessions were devoted to papers presented by Dr. Joseph H. Pratt, State Geologist of North Carolina, Dr. T. A. Mighill, Boston, Mass., Prof. Chas. A. Davis, Peat Expert of the United States Bureau of Mines, M. Max Toltz, St. Paul, Minn., and Prof. R. H. Fernald, Producer Gas Expert of the United States Bureau of Mines.

The arrangements for the meeting were made for the most part under the direction of the president of the society, Dr. Eugene Haanel, Director of the Department of Mines of the Dominion Government.

NATIONAL ASSOCIATION OF MASTER SHEET METAL WORKERS

The National Association of Master Sheet Metal Workers' sixth annual convention was held at Lulu Temple, Philadelphia, Pa., August 10–13. After the formal opening and reports of officials and committees there were lectures on

Wednesday evening on Builders' and Architects' Night illustrated with stereoptican views; The Superiority of Warm Air Heating Systems by Dr. Wm. F. Colbert, the official lecturer of the Federal Furnace League. There were also tests of Toncan Metal by A. T. English; Ingot Iron by J. H. Aurpperle and Tinplate by H. N. Taylor. On Thursday M. G. Sellers gave an address on A Successful Labor Bureau and a committee report followed on How to Obtain Better Prices for New Contract Work. The Friday morning session was opened with an address by Charles S. Prizer, President of the Federal Furnace League, on the relationship between the National Association of Master Sheet Metal Workers and the Federal Furnace League. A report on warm-air furnaces concluded the professional program.

INTERNATIONAL RAILWAY MASTER BLACKSMITHS' ASSOCIATION

A feature of the annual convention of the International Blacksmiths' Association, held in Detroit, Mich., August 16-18 was a trip by special train to Tiffin, Ohio, to visit the works of the National Machinery Company, where over fifty machines were on exhibition most of which were in operation. The machines included forging machines, bolt headers, automatic machines for tapping and burring hot pressed nuts, continuous and automatic rivet machines, vertical roll threaders for handling bolts and long rods, etc. The intention of the visit was to familiarize railway officers and foremen with new designs especially adapted to railway shop service.

SOCIETY OF AUTOMOBILE ENGINEERS

The Society of Automobile Engineers held its summer meeting at Detroit, July 28–31. A great step in advance was made in starting the work of standardizing all things in automobile engineering which would facilitate economic production and benefit the public in both original cost and replacement. This fact was evidenced in the many papers read, among which were Specification and Heat-Treatment of Automobile Material, Henry Souther, Mem.Am.Soc. M.E.; Testing the Hardness of Metal, A. F. Shore; Basis of Motor Car Taxation, Charles T. Terry. Prof. W. H. Bristol, Mem.Am.Soc.M.E., demonstrated some specially prepared apparatus used in connection with the pyrometrical measurement of temperatures in the heat-treatment of steels; F. S. Ward described his new method of grinding spur gears; Eugene P. Batzell presented a paper on his study of slide, rotary and piston valves for gas engines and F. D. Howe summarized for the meeting the matter of ill-smelling and smoky exhausts from gas engines.

AMERICAN SOCIETY OF CIVIL ENGINEERS

A meeting of the American Society of Civil Engineers was held at the Palace Hotel, San Francisco, Cal., August 19. A paper on A Study of the Present Water Supply of the City of Sacramento and a Proposed Means of Improvement was presented by Charles G. Hyde. The following papers were discussed: Pressure Resistance and Stability of Earth, J. C. Meem; Reinforced Concrete Pier Construction, Eugene Klapp; Remedies for Land Slides and Slips on the Kanawha and Michigan Railway, R. P. Black; The Ultimate Load on Pile Foundations: A Static Theory, John H. Griffith.

PERSONALS

George E. Crawley has become connected with the construction department of the Western Union Telegraph Co., New York. Mr. Crawley was until recently associated with the Gold and Stock Telegraph Co., New York.

John T. Croghan has become associated with Stone & Webster Corporation, Pittsfield, Mass. Mr. Croghan was formerly in the employ of the Concord Electric Co., Concord, N. H., as chief engineer.

J. Edmonds Forgy, formerly associated with the E. I. Du Pont de Nemours Powder Co., Wilmington, Del., has accepted a position with the Charles Warner Co. of the same city.

A. L. G. Fritz, recently associated with the Hartford Suspension Co., Jersey City, N. J., as chief draftsman, has become superintendent of construction of the New England Engineering Co., New York.

Albert W. Howe, formerly engineer and representative of the Standard Plunger Elevator Co., New York, has resigned his position to accept that of eastern manager of the H. J. Reedy Co., Cincinnati, O., and has opened an office in New York.

Herman Jakobsson, until recently ordnance designer, Bureau of Ordnance, War Department, Washington D. C., has opened a consulting engineer's office in the same city.

Roy S. King, formerly general superintendent of the Hall-Cronan Co., Dayton, O., is now in the engineering department of the Indiana Steel Co., Gary, Ind.

Thomas H. Mirkill, Jr. has become general manager of the Poole Engineering & Machine Co., Baltimore, Md. Until recently he was connected with the Southward Foundry and Machine Co., Philadelphia, Pa., in the same capacity.

Wm. H. Morse, formerly secretary of the Morgan Construction Co., Worcester, Mass., has become assistant vice-president of the A. Garrison Foundry Co., Pittsburg, Pa.

James O. Pape has severed his connection with the Pittsburg Valve and Fittings Co., Barberton, O., to accept a position with the Chase Grain Co., Chase, Ind.

Geo. M. Peek has accepted the position of mechanical engineer, construction department of the Water Department of St. Louis, Mo.

L. R. Pomeroy, until recently assistant to the president of the Safety Car Heating and Lighting Co., New York, has become chief engineer of the Railway and Industrial Division of J. G. White & Co.

Paul S. Rattle, connected with the Hicks Locomotive & Car Works, Chicago, Ill., will represent that company in Denver, Colo., hereafter.

Edwin B. Ricketts has been appointed supervising engineer of the U. S. Glass Co., Pittsburg, Pa. He was formerly chemist of the New York Edison Co.

Norman B. Roper, formerly identified with the Power & Mining Machinery Co., Cudahy, Wis., as engineer and salesman, has accepted a position with the Cerro de Pasco Mining Co., Peru, South America, in the capacity of mechanical superintendent.

M. W. Sherwood has entered the employ of the Chicago Pneumatic Tool Co., Chicago, Ill. Mr. Sherwood was formerly general inspector of the Board of Aqueduct Commissioners, New York.

Hermann Stephenson has accepted a position with the Brighton Mills, Passaic, N. J. He was formerly instructor of experimental engineering, Cornell University, Ithaca, N. Y.

John A. Stevens has been appointed by Governor Draper to a second term of three years as a member of the Massachusetts Board of Boiler Rules.

Sidney Withington, recently associated with the experimental department of the Walworth Manufacturing Co., South Boston, Mass., has become identified with the electrification department of the New York, New Haven and Hartford Railroad Co., New Haven, Conn.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

American Society of Mechanical Engineers. The Journal. Vol. 32, No. 1–6. *New York, 1910.*

American Society of Municipal Improvement. Proceedings of the 13th annual convention, Birmingham, Ala., October 2–12, 1906. Gift of the Society.

Ciencias Medicas e Higiene. Tomo 2. *Santiago de Chile, 1910.* Gift.

City Planning for Pittsburg. Outline and Procedure. *Pittsburg Civic Commission, 1910.* Gift of J. R. Bibbins.

Engineers Club of Philadelphia. Directory, 1909. *Philadelphia, 1909.* Gift of the Society.

Etude Experimentale du Ciment Armé. By R. Ferret. *Paris, 1906.*

Institut Politechnique de l' Empereur Alexandre II À Kiev. Annales. Book, 1, 1910. *Kiev, 1910.* Gift of Institut Politechnique.

International Railroad Master Blacksmiths' Association. Report of the proceedings of the 16th annual convention, 1908. *Lima, O., 1908.* Gift of the Society.

La France Automobile. Vol. 1–14. 1896–1909. *Paris, 1896–1909.*

Locomotive Actuelle. Etude Generale sur les types recents de locomotives a grande puissance. *Paris, 1906.*

Metropolitan Sewerage Commission of New York. Report, 1910. *New York, 1910.* Gift of the commission.

Michigan Electric Association. Sixth annual convention, August 17–19, 1909. *Detroit.* Gift of the association.

National Commercial Gas Association. Monthly Bulletin. Vol. 1, No. 13–16. *New York, 1910.*

——Proceedings of the 5th Annual Meeting, December 14–17, 1909. *New York, 1909.* Gift of the association.

Natural Gas Association of America. Officers, 1909–1910. Gift of the association.

New York City Docks & Ferries Dept. Report on transportation conditions of the port of New York, with special reference to a joint railroad terminal in Manhattan on the North River above 25th St. *New York, 1910.* Gift of C. Tomkins, Comr. of Docks.

Railway Club of Pittsburg. Proceedings. Vol. 1–7. *Pittsburg, 1901–1908.*

Scranton Engineers Club. Directory, charter and constitution. 1910. *Scranton, 1910.* Gift of the club.

Traveling Engineers Association. Committee reports and subjects for discussion. Eighteenth annual meeting, August 16–19, 1910. *1910.* Gift.

EXCHANGES

American Society of Heating and Ventilating Engineers. Transactions. Vol. 14, 1910. *New York, 1908.*

Municipal Engineers of the City of New York. Proceedings, 1909. *New York, 1909.*

TRADE PUBLICATIONS

Allis-Chalmers Co., *Milwaukee, Wis.* Bull. No. 1054. Allis-Chalmers steam turbines and generators, 43 pp.

Bristol Co., *Waterbury, Conn.* Illustrated catalogue for Bristol's recording instruments for pressure, temperature and electricity, 64 pp.

Broderick & Bascom Rope Co., *St. Louis, Mo.* Underground wire rope haulage as successfully applied in the workings of the Coal Valley Mining Co., Sherrard and Cable, Ill., 25 pp.

Frick Co., *Waynesboro, Pa.* Refrigerating and ice-making machinery, 171 pp.

Handy Index Co., *New York.* Handy Index for architects, engineers, builders and contractors, July 1910, 64 pp.

Industrial Instrument Co., *Foxboro, Mass.* Foxboro Recorder, Vol. 2, No. 3, containing a series of papers about the manufacture and use of instruments, 48 pp.

Lippincott Steam Speciality & Supply Co., *Newark, N. J.* Lippincott faucet, engine indicators, reducing wheels and planimeters, 24 pp.

Manistee Iron Works Co., *Manistee, Mich.* Buttman vertical steam boilers and stokers, 16 pp.

Ohio Brass Co., *Mansfield, O.* Bulletin devoted to electric railway and mine haulage material, 24 pp.

Wm. Wurdack Elec. Mfg. Co., *St. Louis, Mo.* Switches, switchboards panelboards, cabinets and fronts, 11 pp.

UNITED ENGINEERING SOCIETY

New International Year Book, 1909. *New York, Dodd, Mead, & Co., 1910.*

GIFT OF ASSOCIATION OF AMERICAN STEEL MANUFACTURERS

Standard specifications governing the allowable variations in size and weight of hot rolled bars, as adopted by the association, 1910.

Standard specifications governing the chemical and physical properties of bessemer steel rails, as adopted by the association, May 24, 1906.

Standard specifications governing the chemical and physical properties of concrete reinforcement bars, as adopted by the association, 1910.

Standard specifications governing the chemical and physical properties of structural and special open-hearth plate and rivet steel, as adopted by the association, August 9, 1895, revised February 17, 1896, October 23, 1896, April 19, 1902, February 6, 1903.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

043 Lecturer in machine design in university in Canada. Must be a technical graduate and have had experience in the drafting room. Eight months' term, salary $1200.

044 Machine shop foreman, accustomed to the manufacture of heavy machine tools, especially punches, shears, etc. Must have executive ability and be able to produce good work economically.

045 Wanted, in an eastern college, assistant professor of experimental engineering, to take charge of courses in the mechanical laboratory. In replying, state technical education, practical experience, especially in experimental work, and salary expected.

046 Old established manufacturing business needs a business manager, able to take an interest of ten to twenty thousand dollars. Engineering features can be eliminated or separated. Attractive profits have been made for thirty years. Present manager would give part time for one or two year when needed.

MEN AVAILABLE

104 Member, engineer graduate United States Naval Academy. Has served on teaching staff of technical school and university, editorial work, and scientific research for large engineering concern. Wishes responsible position in these or similar lines.

105 Member, with wide experience in engineering, manufacturing and management, soon to complete study of law; desires to connect with law firm, large manufacturers or corporation requiring man of practical and executive ability to handle business involving legal and mechanical work.

106 Young engineer, Junior member, experienced in steel works, industrial engineering; administrative work, steam engineering and operation. Technical graduate.

107 Junior, member technical graduate, desires position as superintendent or assistant, with opportunity to apply broad experience in systematizing and handling men. Mill, foundry or metallurgical work preferred.

108 Graduate Mass. Inst. of Tech. in mechanical engineering; four years' experience in practical shop work, general drafting and minor executive; desires position as draftsman with consulting engineers or assistant superintendent in industrial plant.

109 Junior member, graduate mechanical engineer, experienced manufacturing plant design and installation. At present occupying executive position in manufacturing concern. Desirous of securing similar position in engineering or manufacturing company where chances of advancement are greater. Salary $2400.

110 Member, technical training, 35 years of age. Twelve years excellent experience general machine, foundry and structural business, draftsman, chief draftsman, estimator and travelling engineer. At present, mechanical engineer large machine works and jobbing shops.

111 Experienced civil and mechanical engineer, designing, construction, selling, installation and operation departments of modern power equipment and manufacturing plants; wide personal acquaintance United States, Canada, Great Britain and the continent; successful in dealing with United States and foreign government engineer departments, municipal and other public works; familiar with modern office, shop organization and costs; drafting specifications and contracts; good correspondent and executive; active, energetic and resourceful; eastern Member.

112 General superintendent, mechanical engineer, at present organizing new factory; desires to make change about September 15. Eighteen years executive experience, shop organization and costs, covering machines, tool design and efficiency, production methods, shapes of tools, speeds and feeds, belt tensions and treatments, drop forging and ornamental work, dies of all kinds. Particularly experienced manufacturing machine tools, automobiles and general hardware. Good appearance, very active; highest references. Member, minimum salary, $4000.

113 Technical graduate, over 20 years direct experience in practical affairs of machine shop and foundry. For last 12 years, specialized as superintendent and works manager in modern methods. Demonstrated ability as organizer and executive. Desires position with aggressive growing concern as superintendent or manager; will purchase an interest if desirable.

114 New York member, 30 years' experience designing and superintending manufacture of engines, special and general machinery; power plant, factory revision and installation; process improvement. Desires position with company requiring services of experienced mechanical engineer.

115 Associate, more than fourteen years' drawing room experience; desires to make change, preferably in the East. Would prefer position as checker or squad foreman on rolling mill, steel works, smelting machinery or allied lines.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ALEXANDER, Chas. A. (1899; 1905), Engr. and Contr., Bldrs.' Exch., and *for mail,* 64 Cornell St., Rochester, N. Y.

BAENDER, Fred. Geo., (Junior, 1909), Fife, Ore.

BARBIERI, Cesare (1908), Cons. Mech. Engr., Old Colony Bldg., Dearborn & Van Buren Sts., and 921 Leland Ave., Chicago, Ill.

BENSON, Orville (1901), Pequannock, N. J.

BOYD, John T. (1887), 57 Oliver St., Boston, Mass.

BROOKS, Paul R. (1905; 1909), Estate of Jonathan W. Brooks, Mission, Texas.

CASE, Milo McClelland (Junior, 1909), Supt., Champion Mchy. Co., and *for mail,* 163 Illinois St., Joliet, Ill.

COLE, Cyrus L. (Junior, 1908), 549 66th Ave., Milwaukee, Wis.

CORE, W. Wallace (Junior, 1907), Cons. Engr., 165 Sherman Ave., Newark, N. J.

CRAWLEY, George E. (Junior, 1908), Constr. Dept., Western Union Tel. Co., 195 Broadway, and *for mail,* 548 W. 124th St., New York, N. Y.

CROGHAN, John T. (Associate, 1909), Stone & Webster Corp., Box 845, Pittsfield Mass.

CURTIS, Greely, S. (1897; 1904), Marblehead, Mass.

DAWLEY, Clarence A. (Junior, 1904), Cons. Engr., 39 Cortlandt St., New York, N. Y.

FLANDERS, Ralph E. (Associate, 1908), Springfield, Vt.

FOSTER, Horatio A. (1895), 521 San Fernando Bldg., Los Angeles, Cal.

FOX, William (1909), Asso. Prof. Physics, College of the City of N. Y., 139th. St. and Convent Ave., and *for mail,* 575 W. 183rd St., New York, N. Y.

FREDERICK, Floyd Willis (1907), Mech. Engr., Natl. Board of Fire Underwriters, 45 Buckingham Bldg., Waterbury, Conn., and *for mail,* 315 S. Ind. St., Bangor, Pa.

FRITZ, Aime L. G. (Junior, 1907), Supt. of Constr., New England Eng. Co., 50 Church St., New York, N. Y., and *for mail,* 99 Elmwood St., Woodhaven L. I., N. Y.

GERNANDT, Waldo George (Junior, 1910), Factory Engr., Rapid Motor Vehicle Co., and *for mail,* Box 497, Pontiac, Mich.

GRIMM, Paul H. (1890), Cons. Engr. 311 Spring St., New York and Glen Cove, L. I., N. Y.

HAGLUND, Gustav (Junior, 1909), Jamaica Junction, L. I., N. Y.

HALL, Morris A. (1905; Associate, 1906), care New England Automobile Journal, Times Bldg., Pawtucket, R. I.

HILLYER, George, Jr. (1898; Associate, 1904), Broad River Granite Co., Candler Bldg., and *for mail*, 5 Crew St., Atlanta, Ga.

HOWE, Albert W. (1903), Eastern Mgr. H. J. Reedy Co., 111 Broadway, New York, and *for mail*, Hotel St. George, Brooklyn, N. Y.

HURLEY, Daniel (Junior, 1904), Cons. Engr., 1325 M St., N. W., Washington, D. C., and 42 E. Manning St., Providence, R. I.

HUTTON, Mancius S. (Junior, 1908), Junior Salesman, Am. Radiator Co., Bundy Dept., 104 W. 42nd St., and *for mail*, 257 W. 86th St., New York, N. Y.

INSLEE, Heber Clyde (1907), Engr. on Plant Work, Babcock & Wilcox Co., Bayonne, N. J.

JAKOBSSON, Herman (1907), Cons. Engr., 303 Victor Bldg., 724 Ninth St. N. W., and 3 Stanley Apts., Harvard St., Washington, D. C.

JOHNSTONE, Francis W. (1909), The Natl. Iron & Steel Wks., S. A., Calzada de los Gallos, Mexico City, Mexico, D. F.

KING, Roy S. (1904; 1910), Engr. Dept., Indiana Steel Co., and *for mail*, 609 Jefferson St., Gary, Ind.

LARKIN, Everett P. (Junior, 1906), 372 Bement Ave., West New Brighton, S. I., N. Y.

LAVERY, Geo. L. (1886), 3019 Indiana Ave., and 4300 Ellis Ave., Chicago, Ill.

LEA, Henry I. (1906; 1909), Cons. Gas Engr., 1517 People Gas Bldg., and 6129 Winthrop Ave., Chicago, Ill.

McINTOSH, William (1902), 25 Willow Ave., Plainfield, N. J.

MAROT, Edward H. (Junior, 1903), Hyatt Roller Bearing Co., Newark, and *for mail* 5 Jefferson Ave., South Orange, N. J.

MERSHON, Ralph D. (1900), Cons. Engr., 60 Wall St., New York, N. Y.

MILLER, Herman G. (1908), Armstrong Mchy. Co., Spokane, Wash.

MIRKIL, Thomas H., Jr. (1884), Genl. Mgr., Poole Engr. & Mah. Co., Woodberry, Baltimore, Md.

MITCHELL, Chas. J. (1908), Ch. Draftsman, Fairbanks, Morse Mfg. Co., and *for mail*, 825 Park Ave., Beloit, Wis.

MORSE, William Horace (1901; 1903), Asst. V. P., A. Garrison Fdy. Co., Pittsburg, Pa.

MUMFORD, Edgar Huidekoper (1887; 1892), 27 Compton Ave., Plainfield, N. J.

NORBOM, John O. (1900), Min. Engr., Alta Vista, Berkeley, Cal.

OWENS, Robert B. (Associate, 1892), Secy., Franklin Inst., Philadelphia, Pa.

PAPE, James Otto, (Junior, 1908), Chase Grain Co., Chase, Ind.

PEEK, George Meredith (1892; 1900), Mech. Engr., Constr. Dept., Water Wks., and *for mail*, 5623 Bartmer Ave., St. Louis, Mo.

POMEROY, L. R. (1890; 1909), J. G. White & Co. Inc., 43 Exchange Pl., New York, N. Y., and 24 Reynolds Terrace, Orange, N. J.

RAPLEY, Frederick Harvey (1905), M. Clark & Co., 9 New Broad St., London, England.

RATTLE, Paul S. (Junior, 1908), Rep., Hicks Loco. & Car Wks., 801-17th St., Denver, Colo.

RICKETTS, Edwin B. (Junior, 1908), Supervising Engr., The U. S. Glass Co., 9th and Bingham Sts., and 5901 Alder St., Pittsburg, Pa.

ROPER, Norman Brownell (1905), Mech. Supt., Cerro de Pasco Mining Co., La Fundicion, Peru, S. A.

SARGENT, Chas. E. (1891), 530 Marine Bldg., Chicago, Ill.

SERGEANT, Chas. H. (1895), 57 Rose St., New York.

SHERWOOD, Mather Williams (1909), Chicago Pneumatic Tool Co., Fisher Bldg., Chicago, Ill.

SLOMER, Wm. Frederick (1909), 61 W. Canfield St., Detroit, Mich.

SMITH, William E. (Junior, 1908), Box 95, College Corner, O.

SPRADO, Ralph (1900), Ch. Engr., Dow Pumping Eng. Co., San Francisco, and *for mail*, 911 Grand St., Alameda, Cal.

STEENSTRUP, P. S. (1906), Jacksonville, Ore.

STEPHENSON, Hermann (Junior, 1909), Brighton Mills, Passaic, N. J.

STIMSON, Oscar M. (1906), O. M. Stimson & Co., 1335 Old Colony Bldg., Chicago, Ill.

SYMONS Wilson E. (1899), 900 Postal Telegraph Bldg., Chicago, Ill.

THORNTON, William F. (1909). Mechanicsburg, Cumberland Co., Pa.

THURSTON, George H. (1902), Asst. Mech. Engr., Consol. Goldfields of South Africa, 8 Old Jewery, London, England.

TRASK, Walter H., Jr. (Junior, 1908), Denver Engr. Wks. Co., and *for mail* 845 Pennsylvania Ave., Denver, Colo.

WEEKS, Paul (Junior, 1905), Needles, Cal.

WELLS, J. Barnard (Junior, 1909), Draftsman, A. T. & S. F. Ry. and *for mail*, . 301 S. Boyle Ave., Los Angeles, Cal.

WILEY, James M. (Junior 1909), Elec. Engr., Holly Sugar Co., and *for mail*, Swink, Colo.

WILLISTON, Arthur L. (1896; 1899), care W. W. Simmons, 102 Bay St., Manchester, N. H.

WINTERROWD, William H. (Junior, 1907), Asst. Engr. Mech. Dept., N. Y. Central Lines, and *for mail*, The Arden, E. 18th St., Cleveland, O.

WITHINGTON, Sidney (Junior, 1908), Elec. Dept., N. Y. N. H. & H. R. R. Co., New Haven, Conn.

NEW MEMBERS

ABRAHAMS, M. Landa (Junior, 1910), Inspr. of Mchy., Isthmian Canal Com., Washington, D. C.

ADAMS, John (Junior, 1910), Estimator, Otis Elev. Co., New York, and *for mail*, 4093 Ferris St., Woodhaven, L. I., N. Y.

CUNNINGHAM, George H. (Junior, 1910), Draftsman, Va. Bridge & Iron Co., and *for mail*, Box 487, Roanoke, Va.

DuBARRY, Ed. G., (Junior, 1910), Pittsburg Valve and Fittings Co., and *for mail*, 5321 Penn Ave., Pittsburg, Pa.

CARTER, Harold Thomas (Junior, 1910), Engr., Water Works, Aish Bagh, Lucknow, India.

GLADFELTER, Herbert S. (Junior, 1910), Inspr., Mech. Engr. in charge Levee Mch. with Civil Service, Modoc, Ark.

HENDERSON, Clark T. (Junior, 1910), Elec. and Mech. Engr., Cutler Hammer Mfg. Co., Milwaukee, Wis.

PORTER, Hollis P. (1910), Pres. and Mgr., Schlafli & Porter Co., Engrs., 206 Stewart Bldg., Houston, Texas.

PRICE, William T. (Junior, 1910), Phila. Rep., De La Vergne Mch. Co., 380 Bourse Bldg., Philadelphia, Pa., and Glen Lake, Pitman, N. J.

ROBINSON, Mark (1909), care Mrs. Huntington, 1 Canning St., Waterloo, nr. Liverpool, England.

ROSS, Philip Lawrence (Junior, 1910), Proposition Dept., Babcock & Wilcox Co., Bayonne, and *for mail*, 40 Milford Ave., Newark, N. J.

PROMOTIONS

HENES, Louis G. (1903; Associate, 1910), Mgr., Manning, Maxwell & Moore, Inc., Mgr., Commer. Acetylene Co., Mgr., Ry. Materials Co., 247–249 Monadnock Bldg., San Francisco, and Key Route Hotel, Oakland, Cal.

MAHL, F. W. (1892; 1910), Asst. to Dir. Maintenance and Operation, Union Pacific System and Southern Pacific Co., 135 Adams St., Chicago, and *for mail*, 1019 Michigan Ave., Evanston, Ill.

DEATHS

CLARK, Charles B., March 24, 1910.

DUNCAN, J. D. E., July 13, 1910.

FAULKS, James B., Jr., July 14, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

BAENDER, Fred. Geo. (1909), Mem.Am.Soc.M.E.
CRAWLEY, George E. (1908), Mem.Am.Soc.M.E.
DAWLEY, Clarence A. (1908), Mem.Am.Soc.M.E.
LEA, Henry I. (1908), Mem.Am.Soc.M.E.
MITCHELL, Chas. J. (1909), Mem.Am.Soc.M.E.
MORDEN Chas. Whitney (Affiliate, 1909), 586 Everett St., Portland, Ore.
SARGEANT, Chas. E. (1908), Mem.Am.Soc.M.E.
SERGEANT, Chas. H. (1908), Mem.Am.Soc.M.E.
TYLEE, Don O. (Affiliate, 1909), 755 Franklin Ave., Wilkinsburg, Pa.

STUDENT BRANCHES

CHANGES OF ADDRESS

BASS, L. D. (Student, 1910), Canton, Ill.
BECK, George, Jr., (Student, 1909), 95 Sussex Ave., East Orange, N. J.
BENBOW, J. R. (Student, 1910), 529 High St., Pottstown, Pa.
BERGER, Julius G. (Student, 1909), 104 S. Common St., Lynn, Mass.
BOLGIANO, J. R. (Student, 1909), Security Cement & Lime Co., Security Md.
BOWER, F. A. (Student, 1909), 547 Hancock St., Brooklyn, N. Y.
BUTLER, W. C. M. (Student, 1910), Park Pl., Schuylkill Co., Pa.
CHILDS, J. N. (Student, 1909), Y. M. C. A., Hazelton, Pa.
COLGATE, G. M. (Student, 1910), 509 Erie Ave., Niagara Falls, N. Y.
COMINS, Harold N. (Student, 1909), 701 Whitney Ave., Wilkinsburg, Pa.
COOK, George C. (Student, 1909), 32 Vine St., West Lynn, Mass.
CRANE, Fred L. (Student, 1909), 413 Rebecca Ave., Wilkinsburg, Pa.
DORER, Oscar H. (Student, 1909), 418 Whitney Ave., Wilkinsburg, Pa.
FAIRCHILD, F. P. (Student, 1910), 586-68th Ave., West Allis, Wis.
GARY, F. P., (Student, 1910), Southern Cotton Oil Co., Augusta, Ga.
GLEASON, E. P. (Student, 1910), 2408 Wells St., Milwaukee, Wis.
GRIMES, C. E. (Student, 1909), 113 S. 37th St., Philadelphia, Pa.
GUNKEL, Fred H., Jr., (Student, 1909), Westwood, N. J.
HAM, C. W. (Student, 1910), 215 Arlington Ave., Lexington, Ky.
HARDING, H. C., (Student, 1909), 34 Linden Ave., Middletown, N. Y.
HATMAN, J. G. (Student, 1910), Wyandotte County Gas Co., Kansas City, Kan.
HEISLAR, C. S. (Student, 1909), 1951 S. Homan Ave., Chicago, Ill.
HODGSON, J. H. S., (Student, 1910), 1421 Arch St., Philadelphia, Pa.
JEHLE, Ferdinend (Student, 1909), Heine Safety Boiler Co., 2449 E. Marcus Ave., St. Louis, Mo.
JONAS, M. R. (Student 1909), 2401 Chelsea Ave., Baltimore, Md.
KERR, Geo. W. (Student, 1910), 754 Ross Ave., Wilkinsburg, Pa.
KONSTANKEWICZ, M. J. (Student, 1910), 629 Adams St., Gary, Ind.
LAY, R. P. (Student, 1910), 302 Coolidge Ave., Syracuse, N. Y.
MERRIHEW, L. A. H. (Student, 1910), 86 Oak St., Plattsburg, N. Y.
MEYER, Richard C. (Student, 1909), 119 W. Lanvale St., Baltimore, Md.
MUFFLY, Walter W. (Student, 1910), 21 Chestnut St., Sharon, Pa.
PAGE, W. K. (Student, 1909), 618 Chapel St., Schenectady, N. Y.
ROBINSON, G. E. (Student, 1910), 860 Huntington Ave., Boston, Mass.
SCHUSTER, George (Student, 1909), 324 McLean St., Lincoln, Ill.
SERRELL, John J. (Student, 1909), 81 Myrtle Ave., Plainfield, N. J.

SPOOR, I. H. (Student, 1910), 360 Wisconsin Ave., Oshkosh, Wis.
THOMAS, Felix (Student, 1910), 310 W. 2d St., Dayton, O.
TORRANCE, C. Everett (Student, 1909), 105 Hudson St., Ithaca, N. Y.
WESLEY, Chas. F. (Student, 1909), Box 148, 1421 Arch St., Philadelphia, Pa.
WHAREN, Geo. B. (Student, 1910), 405 Paige St., Schenectady N. Y.
WHEDBEE, Edgar (Student, 1909), 437 N. 5th St., Terre Haute, Ind.
WOHLENBERG, W. J. (Student, 1910), 456 Swissvale Ave., Wilkinsburg, Pa.
WORKMAN, D. M. (Student, 1910), 5 Oak St., Aurora, Ill.

NEW MEMBERS

CORNELL UNIVERSITY

ORBISON, T. E. (Student, 1910), 699 Lawrence St., Appleton, Wis.

PURDUE UNIVERSITY

COFFIN, T. (Student, 1910), 1018 State St., W. Lafayette, Ind
GREEN, J. B. (Student, 1910), R. F. D. 14, Trenton, N. J.
KELLEY, P. W. (Student, 1910), 1008 E. Charles St., Muncie, Ind.
KING, Clifford M. (Student, 1910), Centerville, Ind.
MILLS, J. L. (Student, 1910), 817 Claremont Ave., Chicago, Ill.
SAUERS, John L. (Student, 1910), Tate St., Lawrenceburg, Ind.
SMITH, T. C. (Student, 1910), Chalmers, Ind.
TEMPLIN, E. W., Student, 1910), Univ. of Ill., Urbana, Ill.
WIEST, H. N. (Student, 1910), 172 Juneau Ave., Milwaukee, Wis.

UNIVERSITY OF NEBRASKA

BURLEIGH, W. H. (Student, 1910), 104 Oneida Ave., Davenport, Ia.

COMING MEETINGS

SEPTEMBER—OCTOBER

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

AMERICAN MINING CONGRESS

September 26–October 1, annual convention, Los Angeles, Cal. Managing director, Sidney Norman.

AMERICAN PUBLIC HEALTH ASSOCIATION

September 5–9, annual meeting, Milwaukee, Wis. Secy., W. C. Woodward, Washington, D. C.

AMERICAN SOCIETY OF CIVIL ENGINEERS

September 7, 220 W. 57th St., New York, 8.30 p.m. Paper: Remedies for Landslides and Slips on the Kanawha and Michigan Railway, R. P. Black. Secy., C. W. Hunt.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENT

October 11–16, annual convention, Erie, Pa. Secy., Prescott Folwell, 239 W. 39th St. N. Y.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION

October 10–14, annual convention, Atlantic City, N. J. Secy., H. C. Donecker, 29 W. 39th St., New York.

ASSOCIATION OF EDISON ILLUMINATING COMPANIES

September 6–8, annual meeting, Thousand Islands, N. Y. Asst. Secy., Walter Neumuller, 55 Duane St. New York.

THE COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION

September 21–23, annual convention, Glenwood Springs, Secy., F. D. Monis, 323 Hagerman Bldg., Colorado Springs.

INTERNATIONAL ASSOCIATION OF MUNICIPAL ELECTRICIANS

September 6–9, annual convention, Rochester, N. Y. Secy., Frank B. Foster, Corning.

INTERNATIONAL CONGRESS OF HIGHER TECHNICAL EDUCATION

September 9–11, Brussels, Belgium. Comr., Elmer Ellsworth Brown. Bureau of Education, Department of Interior, Washington, D. C.

INTERNATIONAL CONGRESS OF REFRIGERATION

October 9–12, University of Vienna, Austria. Papers: Constructing and Testing Refrigeration Machinery and Insulating Materials, Application of Refrigeration to Food, Industrial Refrigeration, Railway and Steamship Refrigeration, Legislation and Administration. Chairman of Committee on Transportation, F. W. Pilsbury, 1660 Monadnock Block, Chicago, Ill.

INTERNATIONAL HUNTING CONGRESS

September 5–7, Vienna, Austria. Secy., C. Kunsby, Wiesingerstrasse 8.

INTERNATIONAL MUNICIPAL CONGRESS AND EXPOSITION

September 18–30, Chicago, Ill. Secy., Curc M. Treat, 1107–1108 Great Northern Bldg.

IRON AND STEEL INSTITUTE

September 26–30, Buxton, England. Secy., G. C. Lloyd, 28 Victoria St., London, S. W.

LEAGUE OF AMERICAN MUNICIPALITIES

August 23–26, annual convention, St. Paul, Minn. Secy., John MacVicar, Desmoines, Iowa.

MASTER CAR AND LOCOMOTIVE PAINTERS' ASSOCIATION

September 13–16, annual convention, St. Louis, Mo. Secy., A. P. Dane, Reading, Mass.

MICHIGAN GAS ASSOCIATION

September 9–12, annual meeting, aboard boat "Georgian Bay." Secy. Glenn R. Chamberlain, Grand Rapids, Mich.

NATIONAL ASSOCIATION OF GERMAN-AMERICAN TECHNOLOGISTS

September 1–5, Newark, N. J. Paper: The Activity of Radium and Permanency of the Element with Side-Lights on Transmutation and Alchemy, L. H. Friedburg. Secy., B. A. von Bergen, 842 Broad St.

NATIONAL ASSOCIATION OF STATIONARY ENGINEERS

September 12–17, annual convention, Rochester, N. Y. Secy., Fred W. Raven, 325 Dearborn St., Chiaego, Ill.

NATIONAL CONSERVATION CONGRESS

September 6–9, St. Paul, Minn. Secy., Thomas R. Shipp, Colorado Bldg., Washinton, C. D.

NATIONAL IRRIGATION CONGRESS

September 26–30, annual meeting, Pueblo, Colo., Secy., Arthur Hooker.

NAVAL, MERCANTILE, MARINE AND GENERAL ENGINEERING MACHINERY EXHIBITION

September 1–16, Olympia, London, England. Secy. Frederic W. Bridges, 119–125 Finsburg Pavement, London E. C.

NEW ENGLAND WATERWORKS ASSOCIATION

September 21–23, annual convention, Rochester, N. Y. Secy., Willard Kent Narragansett Pier, R. I.

PACIFIC COAST GAS ASSOCIATION

September 20–22, annual meeting, Los Angeles, Cal. Secy., John A. Britton, 925 Franklin St., San Francisco.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION

September 13–16, Chicago, Ill. Secy., W. E. Emery, West Chicago.

UNION OF CANADIAN MUNICIPALITIES

August 31–September 2, annual convention, Toronto, Ont. Secy., W. D. Lighthall, K. C., Westmount, Que.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
September			P. M.
1	Blue Room Engineering Society	W. D. Sprague	8.00
2	Western Union Electrical Society	H. C. Northen	7.00
7	Wireless Institute	S. L. Williams	7.30
8	Illuminating Engineering Society	P. S. Millar	8.00
9	Western Union Electrical Society	H. C. Northen	8.15
16	Western Union Electrical Society	H. C. Northen	7.00
16	New York Railroad Club	H. D. Vought	7.00
23	Western Union Electrical Society	H. C. Northen	7.00
28	Municipal Engineers of New York	C. D. Pollock	8.15
28	Western Union Electrical Society	H. C. Northen	7.00
October			
5	Wireless Institute	S. C. Williams	7.30
6	Blue Room Engineering Society	W. D. Sprague	8.00
7, 14, 21, 28	Western Union Engineering Society	H. C. Northen	7.00
11	American Society of Mechanical Engineers	C. W. Rice	8.15
13	Illuminating Engineering Society	P. S. Millar	8.15
18	New York Telephone Society	T. H. Lawrence	8.00
19, 20, 21	American Gas Institute	A. B. Beadle	All day
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15

OFFICERS AND COUNCIL

PRESIDENT

George Westinghouse	Pittsburg, Pa.

VICE-PRESIDENTS

Geo. M. Bond	Hartford, Conn.
R. C. Carpenter	Ithaca, N. Y.
F. M. Whyte	New York

Terms expire at Annual Meeting of 1910

Charles Whiting Baker	New York
W. F. M. Goss	Urbana, Ill.
E. D. Meier	New York

Terms expire at Annual Meeting of 1911

PAST-PRESIDENTS

Members of the Council for 1910

John R. Freeman	Providence, R. I.
Frederick W. Taylor	Philadelphia, Pa.
F. R. Hutton	New York
M. L. Holman	St. Louis, Mo.
Jesse M. Smith	New York

MANAGERS

Wm. L. Abbott	Chicago, Ill.
Alex. C. Humphreys	New York
Henry G. Stott	New York

Terms expire at Annual Meeting of 1910

H. L. Gantt	New York
I. E. Moultrop	Boston, Mass.
W. J. Sando	Milwaukee, Wis.

Terms expire at Annual Meeting of 1911

J. Sellers Bancroft	Philadelphia, Pa.
James Hartness	Springfield, Vt.
H. G. Reist	Schenectady, N. Y.

Terms expire at Annual Meeting of 1912

TREASURER

William H. Wiley	New York

CHAIRMAN OF THE FINANCE COMMITTEE

Arthur M. Waitt	New York

HONORARY SECRETARY

F. R. Hutton	New York

SECRETARY

Calvin W. Rice	29 West 39th Street, New York

EXECUTIVE COMMITTEE OF THE COUNCIL

Alex. C. Humphreys, *Chairman*
Chas. Whiting Baker, *Vice-Chairman*
F. R. Hutton
H. L. Gantt
F. M. Whyte

STANDING COMMITTEES

FINANCE

Arthur M. Waitt (5), *Chairman*
Robert M. Dixon (3), *Vice-Chairman*
Edward F. Schnuck (1)
Geo. J. Roberts (2)
Waldo H. Marshall (4)

HOUSE

William Carter Dickerman (1), *Chairman*
Francis Blossom (3)
Bernard V. Swenson (2)
Edward Van Winkle (4)
H. R. Cobleigh (5)

LIBRARY

John W. Lieb, Jr. (3), *Chairman*
Leonard Waldo (2)
Ambrose Swasey (1)
Chas. L. Clarke (4)
Alfred Noble (5)

MEETINGS

Willis E. Hall (5) ,*Chairman*
L. R. Pomeroy (2)
Wm. H. Bryan (1)
Chas. E. Lucke (3)
H. de B. Parsons (4)

MEMBERSHIP

Charles R. Richards (1), *Chairman*
George J. Foran (3)
Francis H. Stillman (2)
Hosea Webster (4)
Theo. Stebbins (5)

PUBLICATION

D. S. Jacobus (1), *Chairman*
Fred R. Low (3)
H. F. J. Porter (2)
Geo. I. Rockwood (4)
Geo. M. Basford (5)

RESEARCH

W. F. M. Goss (4), *Chairman*
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Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
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	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
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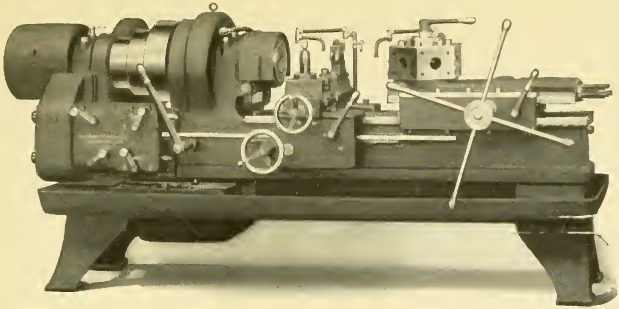

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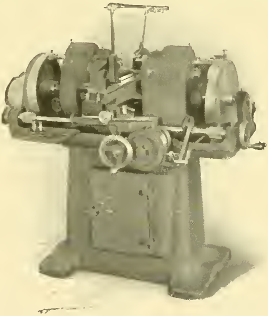

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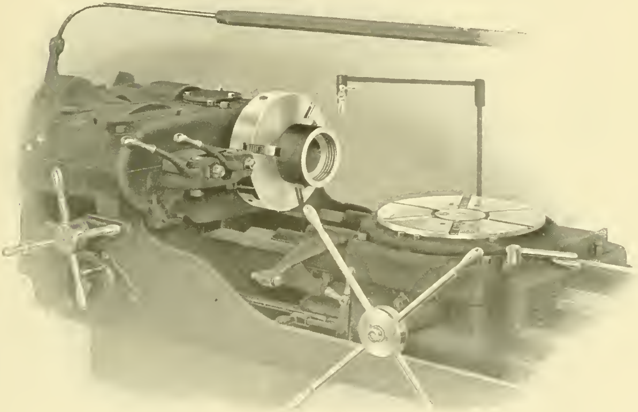

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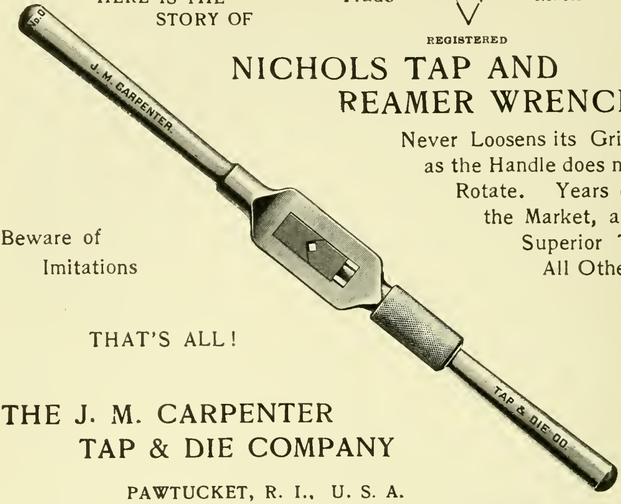

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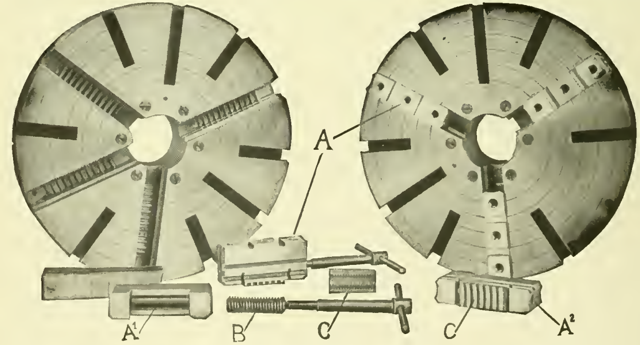

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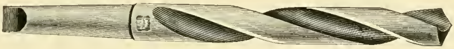

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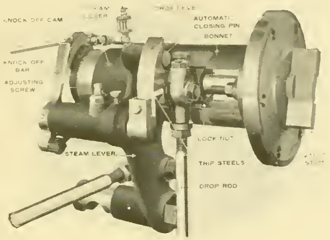

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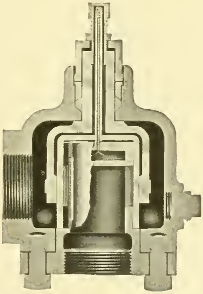

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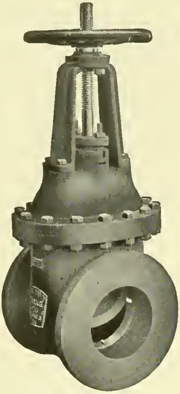
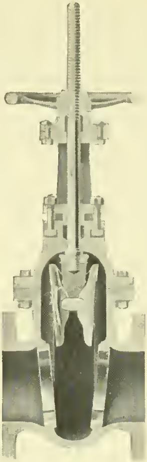
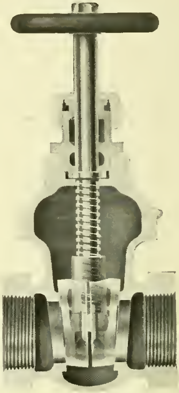


Iron Body Gate Valve, outside view, partly open.



Iron Body Gate Valve, Interior view, open, showing guides on discs and body.



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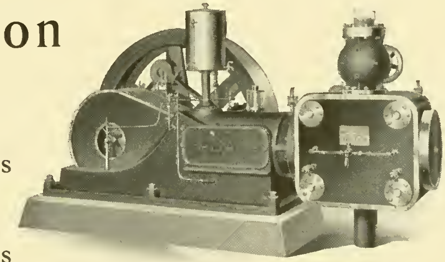

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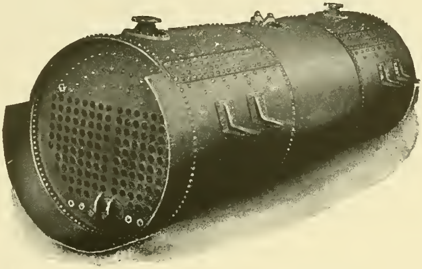

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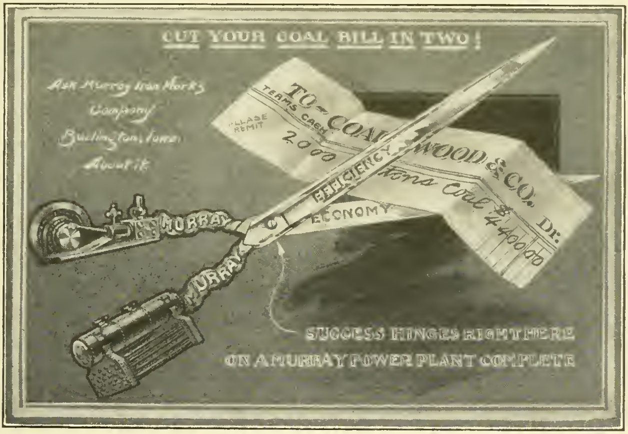

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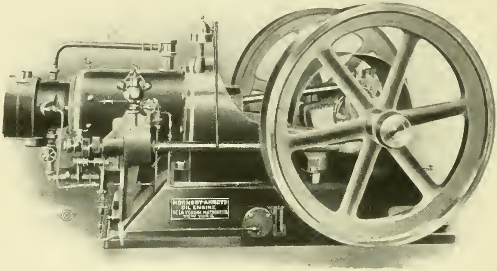

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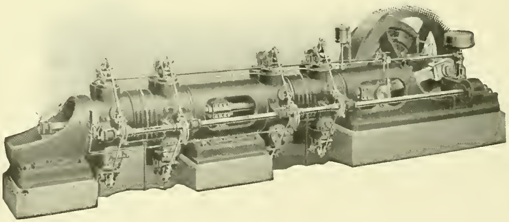

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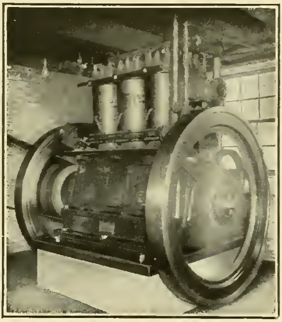

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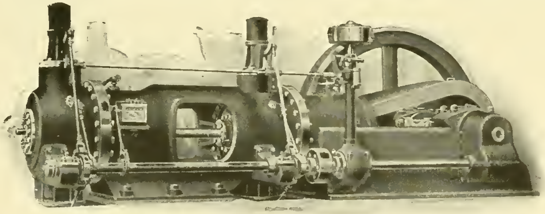

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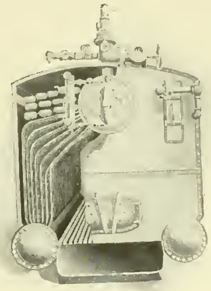

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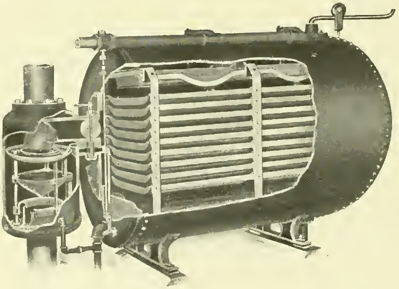

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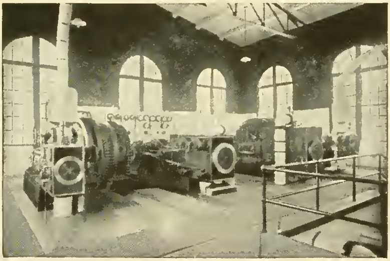

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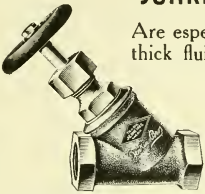

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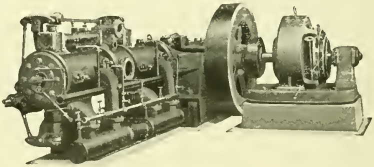

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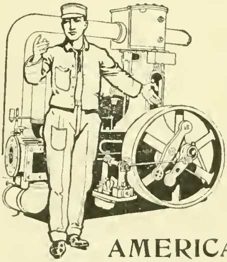

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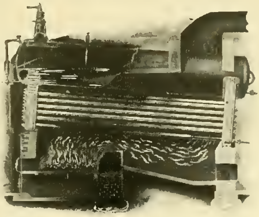

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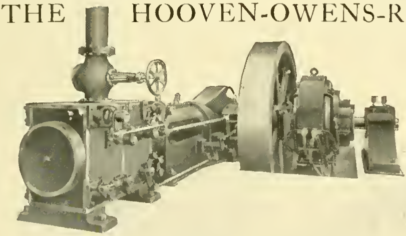

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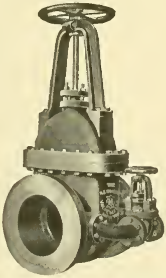

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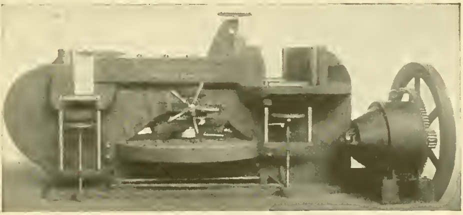

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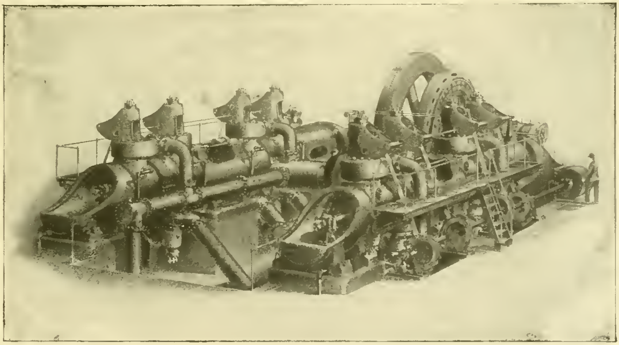

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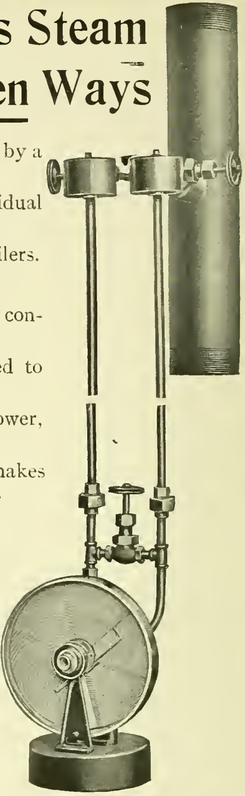

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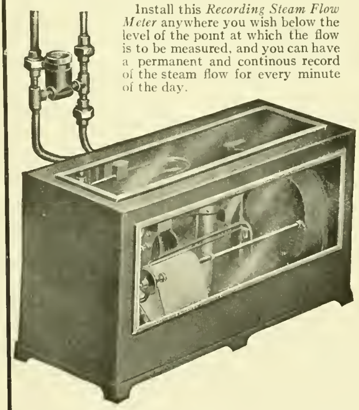

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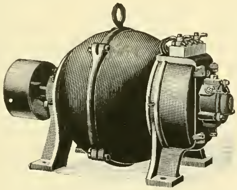

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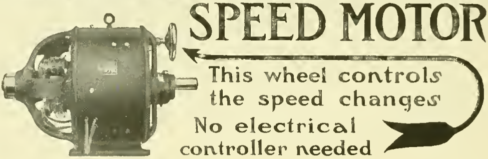
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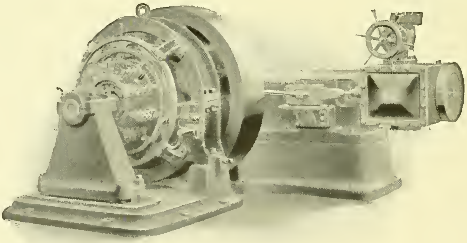

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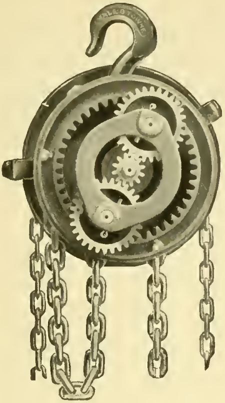

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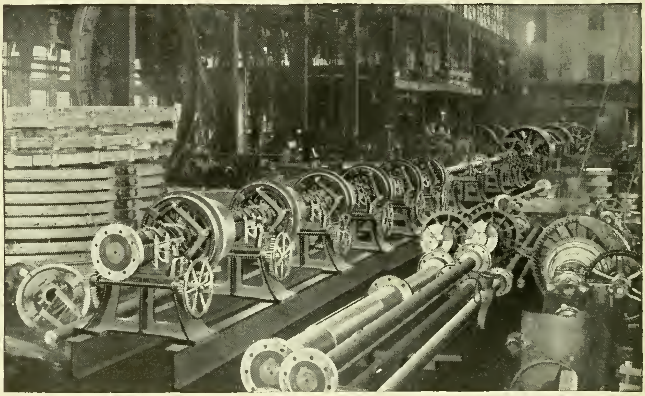

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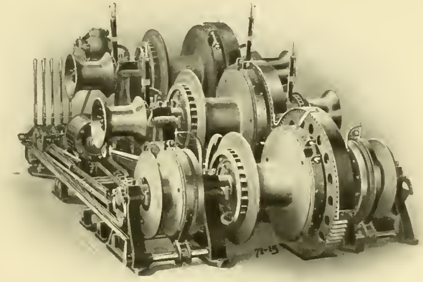

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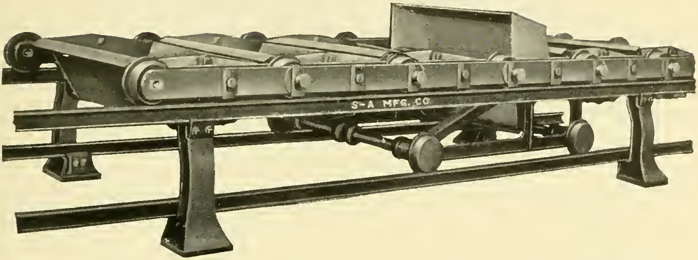

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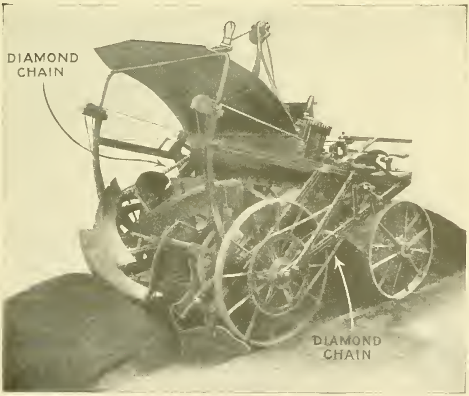

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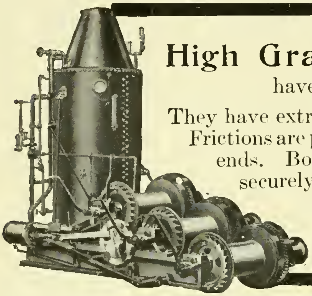

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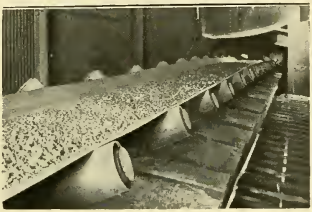

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VOL. 30

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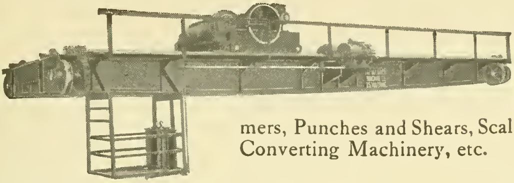

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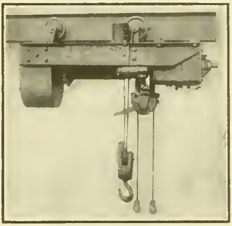

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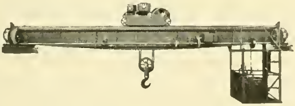

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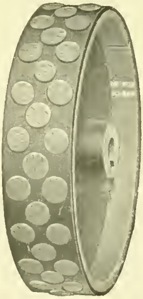

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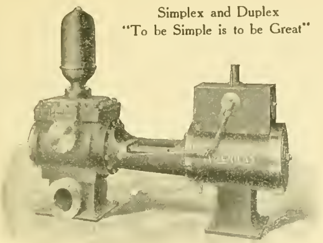

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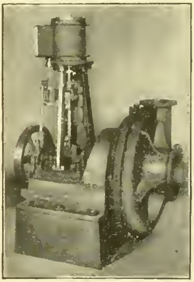

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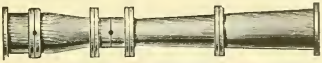

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SECTION 6

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ALPHABETICAL LIST OF ADVERTISERS

Page
Alliance Machine Co ... 31, 48
Allis-Chalmers Co ... 9, 21, 40, 51, 52
Almy Water Tube Boiler Co ... 38
American Engine Co ... 16, 38
American Injector Co ... 42
American Pulley Co ... 47
American Steam Gauge & Valve Mfg. Co ... 42
American Steam Pump Co ... 33, 51
American Vanadium Co ... 54
Amerian Watch Tool Co ... 35
Arnold Co., The ... 56
Ashton Valve Co ... 43
Atlantic Hydraulic Machinery Co. 51

Babcock & Wilcox Co ... 16, 38
Baldwin, Bert. L ... 56
Ball Engine Co ... 15, 38
Blaisdell Machinery Co ... 53
Blake Pump & Condenser Co ... 51
Box & Co., Alfred ... 31, 48
Bridgeport Brass Co ... 10, 43
Bristol Co ... 15, 43
Broderick & Bascom Rope Co . 26, 48
Brown Hoisting Mchy. Co ... 48
Bruce-Macbeth Engine Co ... 40
Buckeye Engine Co ... 12, 38
Builders Iron Foundry ... 33, 51
Bulkley, Henry W ... 43
Butterfield & Co ... 35

Caldwell & Son Co., H. W ... 48
Carborundum Co ... 35
Card Mfg. Co., S. W ... 35
Carpenter Tap & Die Co., J. M .. 4, 35
Chapman Valve Mfg. Co ... 43
Chicago Pneumatic Tool Co ... 53
Cincinnati Gear Cutting Machine Co ... 35
Cincinnati Shaper Co ... 35
Clarkson School of Technology ... 56
Clyde Iron Works ... 28, 48
Conard, William R ... 56
Crosby Steam Gage & Valve Co .. 43

Dallett Co., Thos H ... 53
Davidson Co., M. T ... 51
Dean, F. W ... 56
Dearborn Drug & Chemical Wks. 43
De La Vergne Mach. Co ... 12, 40

Page
Diamond Chain & Mfg. Co .. 27, 47
Dixon Crucible Co., Joseph .. 34, 43
Dodge & Day ... 54
Dodge Mfg. Co ... 24, 47
Dodge Co., J. M ... 49
Du Bois Iron Works ... 16, 41

Eastern Machinery Co ... 49
Engineering Schools & Colleges .. 56
Erie City Iron Works ... 38
Exeter Machine Works ... 42

Fellows Gear Shaper Co ... 36
Franklin Boiler Works Co ... 17, 39

Garvin Machine Co ... 36
Gas Engine & Power Co., and Chas. L. Seabury & Co., Cons. 14, 41
General Electric Co ... 20, 52
Goodrich Co., B. F ... 29, 49
Goulds Mfg. Co ... 33, 51
Goyne Steam Pump Co ... 52
Grant Mfg. & Machine Co ... 36

Harrington & King Perforating Co ... 54
Harrisburg Foundry & Machine Works ... 39
Harrison Safety Boiler Works ... 44
Heine Safety Boiler Co ... 17, 39
Herrick, J. A ... 56
Hewes & Phillips Iron Works ... 9, 39
Hill Clutch Co ... 47
Holyoke Machine Co ... 52
Homestead Valve Mfg. Co ... 44
Hooven, Owens, Rentschler Co. 17, 39
Hoppes Mfg. Co ... 14, 44
Hughson Steam Specialty Co .. 44

Ide & Sons, A. L ... 39

Jeffrey Mfg. Co ... 29, 49
Jenkins Bros ... 16, 44
Jones & Lamson Machine Co. 2, 3, 36

Keasbey Co., Robt. A ... 44
Kennedy Valve Mfg. Co ... 17, 44
King Machine Tool Co ... 36

Page
Laclede-Christy Clay Products Co.......................... 44
Le Blond Machine Tool Co., R. K.. 36
Lidgerwood Mfg. Co............ 49
Link-Belt Co 49
Ludlow Valve Mfg. Co........ 45

McCord & Co................. 45
Main, Chas. T................. 56
Manning, Maxwell & Moore.... 5, 36
Mead-Morrison Mfg. Co......25, 49
Mietz Iron Foundry & Machine Works, August................ 41
Monarch Valve & Mfg. Co...... 45
Morehead Mfg. Co............... 45
Morgan Engineering Co.......... 49
Morris Machine Works........33, 52
Murray Iron Works Co........11, 39

National Brake & Clutch Co..32, 47
National Machine Co............ 36
National Machinery Co......5, 37
National Meter Co............13, 41
Nelson Valve Co...............8, 45
New Process Raw Hide Co..... 37
New York University School of Applied Science............... 56
Nicholson & Co., W. H......... 45
Niles-Bement-Pond Co........... 37
Northern Engineering Works..31, 50

Ohio Injector Co.............. 45
Oneida Steel Pulley Co........ 47
Otis Elevator Co...........23, 50

Paxson Co., J. W............... 54
Peterson, J. Wm 56
Polytechnic Institute of Brooklyn 56
Power Plant Specialty Co...... 45
Power Specialty Co............. 46
Pratt & Whitney Co............. 1
Professional Cards.............. 56
Providence Engineering Works.. 39

Quimby, Wm. E................ 52

Page
Reedy Co., H. J.......... ... 28, 50
Reliance Electric & Engrg. Co. 22, 53
Rensselaer Polytechnic Institute. 56
Ridgway Dynamo & Engine Co..22, 40
Risdon-Alcott Turbine Co...... 52
Robb-Mumford Boiler Co....11, 40
Rockwood Manufacturing Co.... 47
Roebling's Sons Co., John A..26, 50
Roots Co., P. H. & F. M......... 42
Ruggles-Coles Engineering Co.. 42
Russell, Burdsall & Ward Bolt and Nut Co....................5, 37

Scaife & Sons Co., Wm. B....... 46
Shaw Electric Crane Co........ 50
Simmons Co., John..........7, 46
Sprague Electric Co..........21, 53
Standard Roller Bearing Co...34, 54
Standard Tool Co..............5, 37
Stephens-Adamson Mfg. Co..27, 50
Struthers-Wells Co............13, 41
Sturtevant Co., B. F.......... 42
Superior Gas Engine Co........ 41

Tight Joint Co................ 46
Tufts College.................. 56

Wagner Electric Mfg. Co........ 53
Waltham Machine Works.......37
Warner & Swasey Co.........1, 37
Webster Mfg. Co.............. 50
Westinghouse Electric & Mfg. Co..... ....19. 53
Westinghouse Machine Co....19, 40
Wheeler Condenser & Engrg. Co.. 46
Wheeler Mfg. Co., C. H.......... 46
Whiting Foundry Equipment Co. 31, 54
Whiton Machine Co., D. E.....4, 37
Wiley & Russell Mfg Co........ 38
Williams & Wilkins.............. 34
Wisconsin Engine Co..........7, 40
Wood's Sons Co., T. B.......... 48

Yale & Towne Mfg. Co.... ...23, 50

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THE

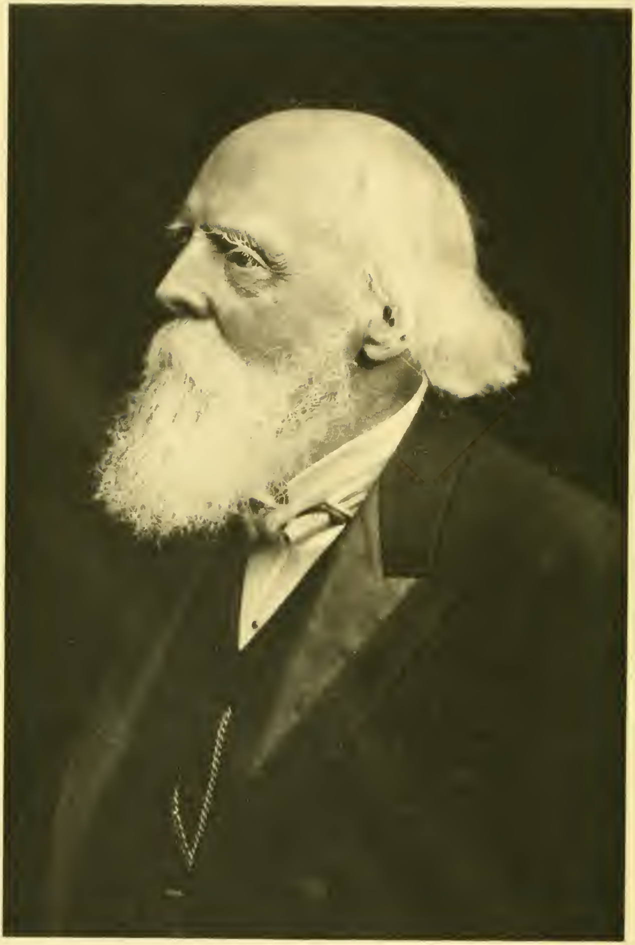
JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

OCTOBER 1910

MEETINGS OF THE SOCIETY: NEW YORK, OCTOBER 11;
BOSTON, OCTOBER 19; ANNUAL MEETING,
NEW YORK, DECEMBER 6-9



Chas. T. Porter

HONORARY MEMBER
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

OCTOBER 1910 VOL. 32 No. 10

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CONTENTS

Society Affairs

Monthly meetings, New York (3); Boston (3); Annual meeting (4); Conservation Congress (6); American Institute of Mining Engineers (7); Director of New Bureau of Mines (7); Amendment to By-Laws (8); Necrology (9).

Papers

A Rotary Cement Kiln, Ellis Soper 1563
Automatic Control of Condensing Water, B. Viola 1579
The United States Battleship North Dakota, C. B. Edwards 1595
A Graphical Method for Calculating Stresses in a Connecting Rod, Winslow H. Herschel 1609
Interchangeable Involute Gearing, Wilfred Lewis 1631
Tooth Gearing, J. D. Steven (in abstract) 1643
Discussion: P. V. Vernon, C. R. Gabriel, Luther D. Burlingame, Daniel Adamson, Thomas Humpage, R. M. Neilson, J. R. Williams 1644

Discussion

A Comparison of Lathe Headstock Characteristics, Prof. Walter Rautenstrauch. Carl G. Barth, The Author 1655
An Experimental Analysis of a Friction Clutch Coupling, Prof. Wm. T. Magruder. H. J. Smith, G. N. Van Derhoef, E. P. Haines, Oberlin Smith, The Author 1659
Test of a 15,000-kw. Steam-Engine-Turbine Unit, H. G. Stott and R. J. S. Pigott. Addition to Closure 1665
General Notes 1667
Personals 1669
Accessions to the Library 1671
Employment Bulletin 1674
Changes in Membership 1676
Coming Meetings 1681
Current Books 1683
Officers and Committees 1684

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The Society as a body is not responsible for the statements of facts of opinions advanced in papers or discussions. C55

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 OCTOBER 1910 NUMBER 10

COMING MEETINGS

The first meeting of the Society for the coming season will be held in the Engineering Societies' Building, New York, on Tuesday evening, October 11. The paper will be by Frank B. Gilbreth; Mem.Am.Soc.M.E., on Fires: Effects on Building Material and Permanent Elimination. This paper was published in The Journal for May and lantern slides will be used showing the results of the author's observations upon the effect of fires in the great conflagrations at Baltimore, San Francisco, Chelsea and elsewhere. Following this, H. deB. Parsons, Mem.Am.Soc.M.E., will show lantern slides illustrating the effect of fire on tall buildings. Prof. Ira H. Woolson, Mem.Am.Soc.M.E., Henry M. Keasby of the National Fire Proofing Co., Wm. D. Grier, Chairman of the National Fire Protection Association, and others concerned with the use of concrete and other fire-proof materials and with fire protection will participate in the discussion.

MEETINGS IN BOSTON

Meetings of the Society in Boston are announced for October 19, November 11 and December 23. The October meeting will be conducted by the Boston Society of Civil Engineers, The American Society of Mechanical Engineers and other engineering societies of the city coöperating. The subject will be An Account of the Destruction of Carthego, Costa Rica by the Earthquake of May

4, 1910. Prof. Thomas A. Jaggar will speak on the geological features and Prof. Chas. M. Spoffard will discuss the effects of the earthquake on different classes of structures. Views will be shown on Carthego taken soon after the earthquake and by photographs of Central American scenes.

The November meeting will be conducted by The American Society of Mechanical Engineers and the December meeting by the Boston Section of the American Institute of Electrical Engineers. It is expected that the meeting in January will take the form of a dinner of the character of the one held last January at which there were some five hundred in attendance, representing the various engineering and architectural societies of Boston and vicinity and many of the technical schools and other organizations.

ANNUAL MEETING

The Annual Meeting of the Society will be held in New York, December 6-9, 1910, the assignment of Papers for the meeting will be made from those published in this number of The Journal and in the November and December Journals. The program for the meeting is in preparation and will be announced as early as possible.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 6-9, 1910, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 2 and 8 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager, at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 9.

d An agent of the Trunk Line Association will validate certificates, Dec. 7, 8, 9. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to Dec. 13, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie Sarnia and Windsor, Ont.

GENERAL NOTES

NATIONAL CONSERVATION CONGRESS

The second National Conservation Congress, held in St. Paul, Minn., September 5–9, 1910, called forth much discussion on the subject of the control of national resources. President William H. Taft, who opened the congress, sounded the key-note of its policy of the conservation of these resources under national regulation and control, discussing the question under seven heads, namely agricultural, mineral, forest, coal, oil and gas, and phosphate lands, and water power sites. Ex-President Theodore Roosevelt in his speech on the following day emphatically urged, in addition to Mr. Taft's recommendations, that the federal government retain control of water power sites as well as coal lands and forests. Other speakers, among them James J. Hill, urged that these resources be left to the control of the individual states, believing the national machine to be too large and too remote and its operation too slow, cumbrous and costly.

The Congress concluded its deliberations by adopting a platform in which it declared the rights of the people "to be natural and inherent and justly inalienable and indefeasible" and that these resources must be "developed, used and conserved in ways consistent both with current welfare and the perpetuity of our people." It further declared that the waterways should be administered in the interests of all the people, and that in doubtful cases there should be coöperation between state and federal agencies; that use of the waters should be made with reference to all other uses and care be taken to prevent defilement; that the policy with regard to swamp lands be continued and extended; that a federal commission empowered to deal with all water powers be maintained; that public lands be withdrawn pending classification and surface rights be separated from mineral, forest and water rights; that mineral lands be leased for a limited period; and that national forests be controlled by the federal government and the forestry service be given larger appropriations. The Congress further expressed itself as opposed to child labor as detrimental to the life and development of the people physically, intellectually and morally, and recommended legislation suitable to this end.

The Society was represented at the Congress by Paul Doty, who acted as chairman of the local board of managers; by E. E. Johnson, J. J. Flather, L. H. Gardner and M. E. R. Toltz.

AMERICAN INSTITUTE OF MINING ENGINEERS

Preparations for the meeting of the American Institute of Mining Engineers, to be held in November in the Canal Zone, are proceeding satisfactorily and more than 100 members and guests have signified their intention of attending. The party will sail from New York on October 21, on the steamer Prinz August Wilhelm of the Hamburg-American line, and the technical sessions will probably be held en-route. Arrangements have been made for the accomodation of the visitors during their stay at the Hotel Tivoli in the Canal Zone.

According to the program now being arranged, the party will arrive at Colon on November 1 and proceed by train to the Gatun Dam, where after luncheon an inspection will be made of the dam and locks. On November 2 a trip will be made by train through the Culebra cut. November 3 is the anniversary of the independence of the Republic of Panama and is observed as a public holiday, with a popular celebration in the city of Panama, including masquerades, fire-works, bull-fights, etc., and no other plans will be made for that date. On November 4 there will be an excursion to the locks and dams at Pedro Miguel and Miraflores; on November 5 an excursion by tug to the Pacific entrance of the Canal, the islands in Panama Bay, etc.; and on November 7 an excursion by train over the relocated line of the Panama Railroad, now in course of construction. The following day will be occupied in the return to the steamer at Colon.

It is further planned to stop en route at Havana and Kingston, and returning at Port Limon, Kingston and Fortune Island, arriving in New York on November 15.

The rapid progress of work on the Isthmus which will in the course of not very many months obscure the many features of construction and methods of operation now open to inspection, makes a trip to Panama at this time especially valuable and interesting to engineers.

The following members of the Society have accepted the invitation of the American Institute of Mining Engineers to join in this meeting: Prof. William Kent, Charles Kirchhoff, R. V. Norris, H. H. Porter, David B. Rushmore, C. M. Russell, W. L. Saunders, F. W. Scarborough, John M. Sherrerd, S. D. Warriner and Walter Wood.

DR. J. A. HOLMES DIRECTOR OF THE NEW BUREAU OF MINES

Dr. Joseph Austin Holmes, Mem.Am.Soc.M.E., who has just been appointed director of the new Bureau of Mines, has for some time past been an eminent officer of the Geological Survey. Mr. Holmes was graduated from Cornell in 1881, and after visiting extensively the mining regions of this country and Europe, occupied for ten years the chair of geology in the University of North Carolina. He resigned from this work to become state geologist of North Carolina and was appointed to the head of the department of mines and metallurgy at the St. Louis Fair in 1904. When the Government fuel investigations were authorized by Congress Dr. Holmes was offered its supervision and has since then been engaged in the examination of coal-fields in a way which has aided both consumers and producers. Dr. Holmes has done much to introduce safety devices into the mines and inaugurated the recent movement for mine rescue work, which includes three state and twelve government mine rescue stations.

AMENDMENT TO BY-LAW 22

The following is the correct text of the amendment to By-Law 22:

B 22 The Finance Committee shall consist of five Members or Associates. The term of office of one Member of the Committee shall expire at the end of each Annual Meeting. This Committee shall, under the direction of the Council, have a supervision of the financial affairs of the society, including the books of account. The Committee may cause the accounts of the Society to be audited and approved annually by a chartered or other competent public accountant. The Committee shall hold monthly meetings for the audit of bills and such other business as shall come before it and shall deliver to the Secretary for presentation to the Council at the end of each fiscal year, a report of the financial condition of the Society for the past year, and also shall present therewith a detailed estimate for the probable income and expenditure of the Society for the following twelve months. It shall make recommendations to the Council as to investments, and when called upon by the Council, advise upon financial questions. It shall have charge of the making of all contracts and other obligations to pay money in the Society's work and the ordering of all expenditures thereunder.

NECROLOGY

CHARLES T. PORTER

Charles Talbot Porter, Hon.Mem.Am.Soc.M.E., a charter member of the Society and recipient of the John Fritz Medal for his "work in advancing the knowledge of steam engineering and for improvements in engine construction," died in New York, August 28, 1910, at the home of his son, Louis Morgan Porter.

Mr. Porter was born at Auburn, N. Y., January 18, 1826. He was descended from a notable line of New England ancestors including, on his father's side, the Rev. Jonathan Edwards, and on his mother's side, Governor John Winthrop of Massachusetts and Governors Saltonstall and Winthrop of Connecticut. He was graduated from Hamilton College in 1845 and at the fiftieth reunion of the class presented the Half-Century Annalist's Letter, a feature of the annual meetings of the Hamilton alumni. After graduation he read law in his father's office in Auburn, and was admitted to the bar in1847. The next year he married Harriette S. Morgan of Aurora, N. Y., and their married life was unbroken until within a few weeks of Mr. Porter's death, when Mrs. Porter died.

After practicing his profession for six or seven years, first at Rochester and afterwards in New York City, Mr. Porter became interested in mechanics in connection with a stone-dressing machine invented by one of his clients, which failed to operate satisfactorily. Believing that the fundamental principles of the machine were correct Mr. Porter went to work to improve it, picking up by the way a knowledge of drafting and designing, and therein brought out his latent mechanical ability. The stone-dressing machine was driven by a steam engine which he desired to run at high speed, but the governor was of the usual simple fly-ball type which could not be speeded up and consequently the regulation of the engine was faulty. To remedy this defect Mr. Porter was led to design and perfect his well-known central counterpoise type of governor which has since carried his name.

Subsequently came the development of the high-speed Allen steam engine, later known as the Porter-Allen engine, which was essentially the life-work of Mr. Porter. The first engine was built in this country and shown at the London Exhibition of 1862, equipped with the Porter governor, and operating non-condensing. In 1867 at the French Exposition five engines were installed, the only high-speed engines exhibited.

The exhibit at London and subsequent attempts to sell engines of this type in England showed the demand to be entirely for condensing engines. This brought about the development by Mr. Porter of a jet condenser to be direct-connected to his engines, with an air pump adapted to the high speed at which the engines ran. The building of these engines was begun in England in 1864.

In his work in steam engineering Mr. Porter became associated or intimately acquainted with many of the early distinguished engineers, notably with John F. Allen and Charles B. Richards. Mr. Allen had originated a link and valve motion for steam engines, well adapted for use with the Porter counterpoise governor, and it was the combination by Mr. Porter of this mechanism with his governor, together with Mr. Porter's advanced ideas upon high rotative speeds and methods of engine construction that resulted in the Porter-Allen engine.

Along with the study of steam economy was the need of a steam-engine indicator adapted to high speeds. This led to the design by Mr. Richards of the first indicator to meet these requirements. The patents were acquired by Mr. Porter and an instrument was shown in connection with the engine at the London Exhibition. It was shortly afterwards manufactured by Elliott Brothers of London.

In the early manufacture of his engines, many practical difficulties had to be met owing to the crudeness of machine shop methods. Numerous devices and systems of manufacturer were introduced by Mr. Porter to attain the accuracy, without which successful high-speed machinery would be impossible.

In 1868 Mr. Porter returned from England, formed a partnership with Mr. Allen and began the manufacture of engines in a small shop in Harlem, N. Y. During the three years of business depression, beginning with 1873, the manufacture of the engines was discontinued, but later was begun at the Hewes and Phillips Iron Works at Newark, N. J., under Mr. Porter's own name. They have since been manufactured by the Southwark Foundry and Machine Company at Philadelphia.

In 1880 Mr. Porter installed a high-speed steam engine in the Edison laboratory at Menlo Park, N. J., which marked the beginning of direct-connected generators. Following this, the first of a series of engines for so-called steam dynamos was constructed for the Edison Station at Pearl Street, New York, each independently driven by a direct-coupled engine.

While these events are important in the history of the high-speed engine for electric generating, the introduction of Mr. Porter's engines into rolling-mill work was of even greater moment. The early processes were deliberate because man was habituated to slow movements. The first power came from the slow-turning water wheel, later from the slow-speed steam engine. Faster movements were obtained through gears and belts and then came the direct-connected, easily controlled high-speed engine.

At the first Annual Meeting, in 1880, of The American Society of Mechanical Engineers, Mr. Porter read a brief paper upon The Strength of Machine Tools, and he has since presented numerous others. At the beginning of the manufacture of the Richards indicator, he prepared for the makers, Elliott Brothers of London, a brief treatise on the Steam Engine Indicator, and in 1874 this was revised and very much enlarged by him and brought out simultaneously in London and New York. This contained the tables of the properties of saturated steam which so long remained a standard, based upon the experiments of M. Regnault. Very recently he published his Engineering Reminiscences, which are an interesting and valuable account of many incidents in the development of steam engineering. Mr. Porter was a member of the Board of Judges at the Centennial Exposition of 1876.

ALBERT SPIES

On August 16, 1910, Albert Spies, a Member of the Society, editor and proprietor of Foundry News, died suddenly at his home 40 Glenwood Ave., Jersey City, N. J. He was born in New York City, July 20, 1862, and received his early education from tutors and at the Hoboken Academy. When only 19 years old he graduated from Stevens Institute of Technology, and for a number of years engaged in engineering practice and technical journalism. In 1893 he became editor of Cassier's Magazine, and in 1904 also assumed the editorial conduct of the Electrical Age. For several months he brought out both papers practically unaided until the pressure of work forced him to relinquish his activities on the latter journal in January 1906. In the fall of 1906, following the death of Louis Cassier, Mr. Spies severed his connection with both papers and in February 1907 became editor of the Electrical Record, continuing until early in this year when he resigned to bring out his own paper, Foundry News. Only four issues were published prior to his death.

Mr. Spies was a member of the Engineers' Club and the American Institute of Mining Engineers, as well as an Associate member of the American Institute of Electrical Engineers. In 1895 he married Miss Gretchen A. Weisker, who, with a son, survives him.

JOHN EDWARDS McKAY

John Edwards McKay was born February 22, 1837 in New York, and received his early education in the public schools and in the Free Academy, now the College of the City of New York. In 1852 he began a two years apprenticeship with Charles W. Copeland of New York and in 1854 entered the drawing-room of the Morgan Iron Works as draftsman and machinist. In May 1859 he was appointed third assistant engineer, U.S.N., from which post he resigned after serving one year, and was again employed by Copeland and by the Coast Survey. In August 1862 he was reappointed to his former grade in the Navy, in December promoted to second assistant, and in May 1864 made first assistant, retaining this position for two years. At that time men in the service of the Navy with practical experience as well as ability to design and make drawings were much in demand, and as Mr. McKay was well equipped in these respects he was ordered to shore duty at Washington, D. C., where under the direction of Benjamin F. Isherwood, Hon.Mem.Am.Soc.M.E., chief of the Bureau of Steam Engineering, he made designs and drawings of marine engines, boilers, etc., for many of the government war-boats. From 1868 to 1872 Mr. McKay was superintendent of the Wood and Mann Engine Company, Utica, N. Y., designing and constructing many steam engines, rolling-mills, saw-mills, etc. He invented at this time a very excellent automatic variable cutting-off for steam engines.

In 1872, at the request of Mr. Tracey, chief engineer of the Croton Aqueduct, Mr. McKay severed his connection with the Wood and Mann Company and entered upon a public service career. During the long period dating from 1872 until his death on May 12, 1910, Mr. McKay was connected successively with the Department of Public Works, the Department of Water Supply and the Department of Water Supply, Gas and Electricity of New York City, and was prominently identified with the many important improvements and extensions in connection with the water supply of the Boroughs of Manhattan and the Bronx, as they are now called, and with the care and maintenance of the system.

Included in the work done by Mr. McKay was the design and supervision of the construction of the tower, chambers, gates, screens, pipes, etc., in connection with the storage reservoir on the west branch of the Croton River at Boyds Corners, Putnam County, N. Y.; the design and preparation of the plans for the storage reservoir on the middle branch of the Croton River near Brewster's Station, Putnam County, N. Y.; the design and drawing of the junction gate-houses and appurtenances, at 113th Street and Amsterdam Avenue and at 93d Street near Columbus Avenue, New York City, and the drawings of the six lines of four-foot pipes between these gate-houses for the replacement of the old aqueduct between those points; the design and drawings of the first successful submarine pipe between Manhattan and Blackwells Islands for a supply of Croton water to the institutions on the latter; in 1876 the design and drawings and superintendence of the installation of the five-million gallon pumping engine now in the High Bridge Pumping Station, and also the superintendence of the six-million gallon pumping engine in that station; the original studies and plans of the High Service Pumping Station, machinery, boilers, stand-pipe and tank, etc., between 97th and 98th streets near Columbus Avenue, New York City; the design and drawings and the superintendence of installation of a specially designed quick-action 36-inch valve in the gate-house of the Central Park reservoir for the control of a fire line to the lower part of Manhattan; drawings in connection with the Fourth Avenue improvement work from 42d Street to the Harlem River and the supervision of construction on this work. From 1903 until the time of his death Mr. McKay had responsible charge of the Croton, the Bronx and the Byram water sheds and the storage reservoirs there, including the dams, gate-houses, aqueducts, pipelines and appurtenances and the distributing reservoirs in the city, and was responsible for the proper conservation of the storage and the flow through the aqueducts to New York City.

Besides being a member of this Society, Mr. McKay was a member of the American Society of Civil Engineers and the Engineers Club. At the time of his death Mr. McKay resided in White Plains, N. Y.

CHARLES B CLARK

Charles B. Clark, Member of the Society, was born at Bangor, Me., June 20, 1858, and died March 24, 1910. He was educated in the public schools of Bangor and in 1876 began an apprenticeship of five years with the Hardy Machine Company, Biddeford, Me., during which time he studied mechanical engineering under a private tutor. In 1881 he was employed as an engineer on a steamboat and in 1882 worked as journeyman in the shops of the Lawrence Machine Company, Lawrence, Mass., where he also attended the evening technical schools. He was subsequently employed as superintendent of the construction of machinery for the Detroit Dry Dock, Detroit, Mich., the Dunford and Alverson Dry Dock, Port Huron, Mich., and the Simpson Dry Dock, East Boston, Mass. In 1889 he returned to the Lawrence Machine Company as superintendent and general manager, leaving this concern three years later to become manager of the Orono Pulp Company, Orono, Me. Four years later he went to New York where from 1896 to 1898 he acted as manager of the Merrimac Paper Company of Lawrence, Mass. Since February 1898 he had been general superintendent of the Eastern Manufacturing Company's mills, South Brewer, Me.

CHARLES A. FERRY

Charles A. Ferry, Associate Member of the Society, died at Phoenix, Arizona, May 2, 1910. He was born at Utica, N. Y., September 1, 1851 and prepared for college at the Montreal High School. After a year at McGill College he entered Yale from which he was graduated in 1872 with the degree of B.A. He remained in New Haven for three years doing graduate work and in 1875 went to Chicago where he studied law in the office of Judge Upton. Shortly afterwards he became interested in manufacturing and was engaged in the manufacture of steel railway couplers, in 1891 becoming president of the Chicago Tire and Spring Company. For several years before his death Mr. Ferry was not engaged in active business, but was always interested in the development of the science of modern times as applied in all directions.

JOSEPH GARBETT

Joseph Garbett, Member of the Society, who was for many years prominently identified with the mechanical industry of Minneapolis, died at his home in that city August 22, 1910. He was born in Shropshire, England, January 7, 1852, in which town he received his early education, and where he spent the first years of his commercial life in the Horshay Iron Works, and later was associated with the Coldbrookdale Iron Works, becoming superintendent of the latter at the age of twenty-three. In 1879 he left England, going direct to Minneapolis and entering the employ of O. A. Pray and Company, manufacturers of flour and saw-mill machinery, as foreman and patternmaker. He steadily developed into a thorough and able mechanic and when the Twin City Iron Works was established he, with O. P. Briggs, constituted the firm, Mr. Garbett serving as chief engineer. It was here that he designed the Twin City Corliss engine which is so favorably known throughout the country today. When the Twin City Iron Works was absorbed by the Minneapolis Steel Machinery Company in 1902, Mr. Garbett was prominent in its affairs, becoming mechanical engineer of that company as well as a director.

In steam engineering Mr. Garbett was an accepted authority. For the past five years he had devoted much time to gas engines and gas producers. He spent several years abroad studying the various types of foreign power plants of this type, and finally adopted the Muenzel, a German engine, as the foundation of a gas engine for American manufacture. To this he applied his skill and engineering ability and developed one of the most successful gas engines and suction producers in use in this country today.

THE ROTARY KILN

By Ellis Soper, Detroit, Mich.

Member of the Society

Early Development. In the manufacture of Portland cement, the methods used at the present time are quite crude, but even so, the progress made in many departments has been very rapid, particularly in the burning department. In approximately 90 per cent of the mills in this country, pulverized coal is used as a fuel and with few exceptions the total burning cost, including the fuel, represents from one-third to one-half of the total cost of manufacture per barrel. Improvements on the present system are daily being made and experiments on a large scale are being carried on by many of the manufacturers.

2 It must be remembered that the first rotary kiln was manufactured about 1885 and not until 1895 was the rotary type considered a success. The plants of Germany and England and also of this country utilized vertical or stationary kilns, which are much more economical in point of fuel consumption but very costly on account of the excessive hand labor necessary.

3 In 1885 Ernest Ransom patented a rotary kiln in England. About a year later Alphonse de Navarro purchased the American rights to this patent and built the first rotary kiln in this country in a mill from which the present great Atlas Company was evolved. It was 5 ft. in diameter by 40 ft. long. The first fuel tried was wood, but a sufficient temperature for clinkering could not be obtained and petroleum was utilized. The cost of the petroleum became excessive and in 1895 (only 15 years ago) pulverized coal was first tried as a fuel in the Atlas mill. To the American engineer and financier is due the wonderful growth of the business and especially the development of the rotary kiln. It was used commercially and developed here before being adopted in Germany and England where the industry originated and was much older. The development of the kiln from

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

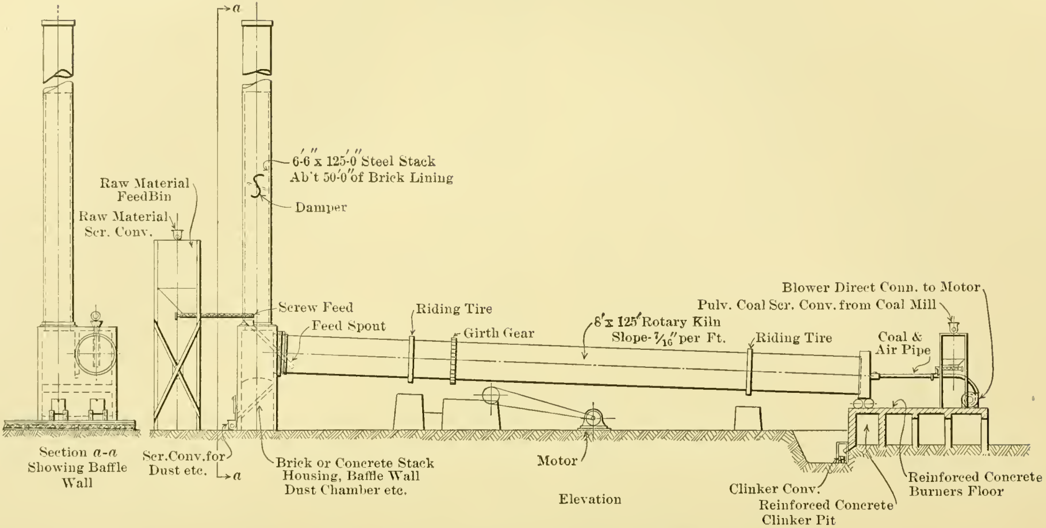

Raw Material FeedBin
Raw Material Scr. Conv.
6'6" x 125'0" Steel Stack Ab't 50'0" of Brick Lining
Damper
a
Screw Feed
Feed Spout
Riding Tire
Girth Gear
8' x 125' Rotary Kiln Slope-7/16" per Ft.
Riding Tire
Blower Direct Conn. to Motor
Pulv. Coal Scr. Conv. from Coal Mill
Coal & Air Pipe
Section a-a Showing Baffle Wall
Scr.Conv.for Dust etc.
a
Brick or Concrete Stack Housing, Baffle Wall Dust Chamber etc.
Motor
Elevation
Clinker Conv.
Reinforced Concrete Clinker Pit
Reinforced Concrete Burners Floor

FIG. 1 TYPICAL INSTALLATION OF AN 8-FT. BY 125-FT. ROTARY KILN

its original size of 5 ft. in diameter by 40 ft. long to one 12 ft. in diameter by 232 ft. long indicates a remarkable growth. Whether the limit in size has been reached is a question yet to be determined. Until the last three or four years the 6-ft. by 60-ft. kiln was the standard, and when Mr. Edison installed his 9-ft. by 150-ft. kilns he was laughed at, but the present manufacturers have him to thank for the biggest single advance step in the history of the industry. The main ideas in developing the rotary kiln appear to be increase in output, decrease in fuel consumption per barrel and decrease in the amount of machinery operating; in other words, *concentration.* But it is questionable which is the better proposition, a mill with one large unit producing 2000 barrels per day, or a mill with four smaller units producing the same output. Allowing for the ordinary operating difficulties and shutdowns due to repairs and other ordinary causes, the total output of the one-unit mill, we believe, will be considerably less than that of the four-unit mill. Whether the saving in fuel consumption of the larger unit will make up for this decrease in production is a question to be considered.

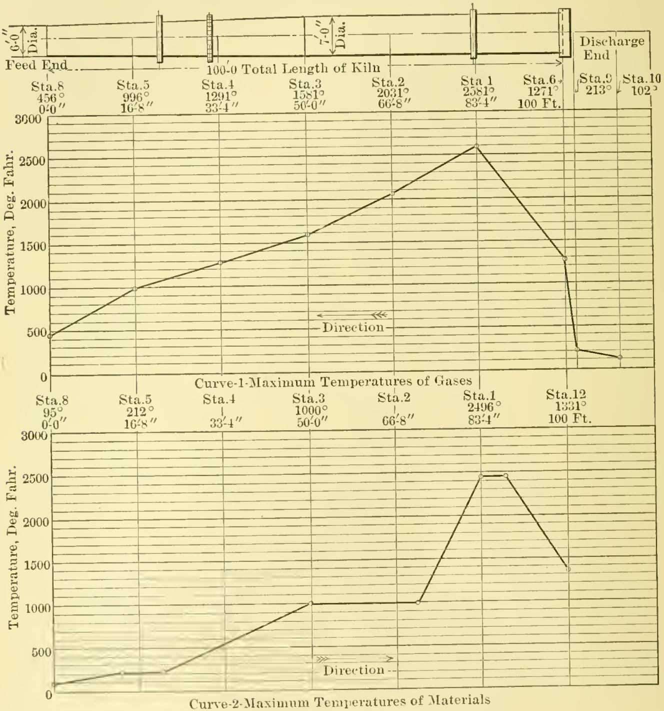
4 *Uses of the Rotary Kiln.* The rotary kiln has lately been utilized successfully in burning lime, drying materials of varied character and in driving off the oxides in iron ores. A 7-ft. by 100-ft. kiln is being successfully used in burning lime, and a production of 9 lb. of lime to 1 lb. of fuel has been secured. The process is continuous and we believe it will eventually be widely adopted. As a direct-heat rotary dryer, it is the best in point of production that can be installed and where a large production is desired, a proper installation is ultimately as economical as the majority of the so-called patent dryers.

5 The Jones "Step-Process" of reducing iron ore direct to metallic iron by use of the rotary kiln is very interesting, and is now practically past the experimental stage. Crushed ore is passed through a rotary kiln 8 ft. by 120 ft., in which a reducing flame is maintained. The coal saving over the present blast furnace method is approximately 70 per cent. The following is a comparative statement of the fuel consumption per ton of steel:

Jones Step Process		Ordinary Process	
Kiln for heat	225 lb.	Blast Furnace	3000 lb.
Kiln for reduction	400 lb.	Puddling Furnace	500 lb.
Puddling Furnace	500 lb.		
Total	1125 lb.	Total	3500 lb.

Saving, 2375 lb. fuel per ton steel

6 *The Rotary Kiln in Cement Manufacture.* The most important use of the rotary kiln, however, is in the burning of cement clinker. The following is a general description of the design, installation, operation, etc., of an 8-ft. by 125-ft. kiln, together with some tests on kilns of other sizes.



Curve-1-Maximum Temperatures of Gases

Curve-2-Maximum Temperatures of Materials
Calculated from Gas Temperatures
Note:- Temp's at Sta's B,1, 12 Actually Observed

Fig. 2 Temperature of Gases and Materials in a 6-ft. and 7-ft. by 100-ft. Rotary Kiln

7 In the manufacture of Portland cement there are, roughly, three stages:

a Preparation of the raw materials, which consists of quarrying the rock and shale or clay, crushing and drying, and pulverizing the proper mixture to an average fineness of 90 to 98 per cent through a 100 mesh sieve.

b Burning or clinkering the mixture to a degree of temperature (about 2600 deg. fahr.) sufficient for the fusing of the powdered material into small greenish-black clinkers about the size of beans.

c Reducing or grinding this clinker to the required fineness, generally 95 per cent through a 100 mesh sieve.

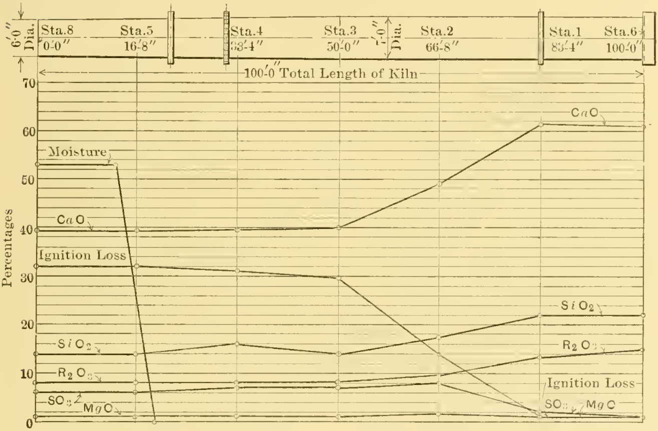


FIG. 3 CHEMICAL CHANGES IN A 6-FT. AND 7-FT. BY 100-FT. ROTARY KILN

8 Fig. 1 shows a typical installation of an 8-ft. by 125-ft. kiln. The raw mix or kiln feed enters the stack end of the kiln, either by gravity or by screw conveyor. The kiln is lined throughout with nine inches of high refractory magnesia brick and is set at an incline of $\frac{3}{8}$ to $\frac{3}{4}$ in. per ft., which allows the material to travel slowly towards the other end of the kiln, from which it discharges into a conveyor, cooler or elevator. A mixture of air with gas, oil or pulverized coal is blown into the discharge end of the kiln by means of compressed air furnished by an air compressor or blower. When ignited, this mixture of air and combustible forms a flame or blast

of variable length which comes into contact with the feed and drives off the moisture and then the gases, after which clinkering takes place at about 2600 deg. fahr.

9 The exact temperatures at different points throughout the kiln were measured in a 7-ft. by 100-ft. kiln operating upon the wet process in which the kiln feed contained 50 per cent moisture. The temperatures were taken by means of a Le Chetelier pyrometer by inserting the porcelain tubes through holes previously drilled through the kiln shell and lining. The kiln revolved very slowly (about one revolution in from one to four minutes) and the temperatures of the gases were accurately determined. The temperatures of the material

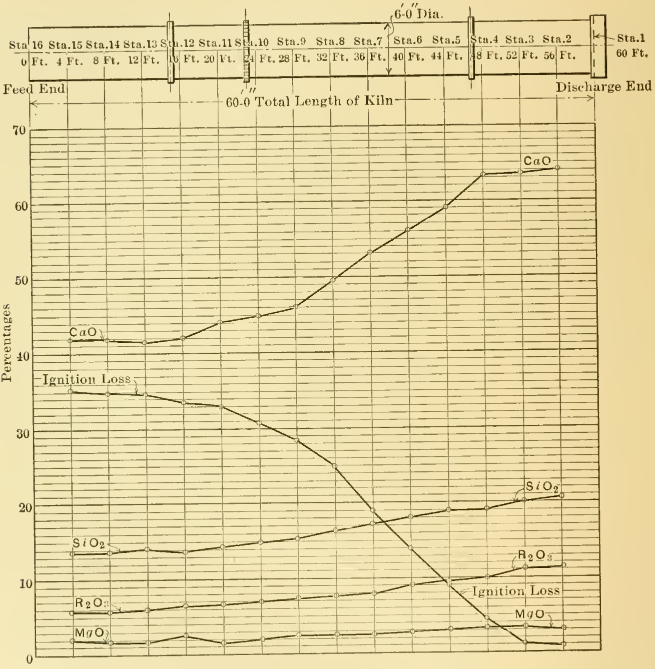


Fig. 4 Chemical Changes in a 6-ft. by 60-ft. Rotary Kiln

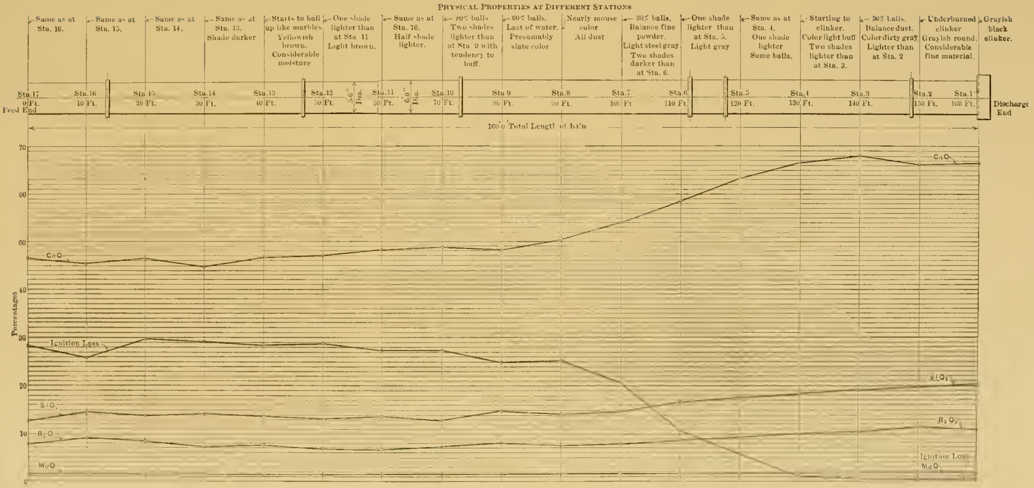


FIG. 5 CHEMICAL AND PHYSICAL CHANGES IN A 6-FT. BY 160-FT. ROTARY KILN

were calculated from this data, as it was very difficult to determine the temperatures of the material without breaking the porcelain tubes. These results were plotted as shown in Fig. 2. Samples of the material were also taken for analysis at points of temperature observations, and the results plotted in Fig. 3.

10 Fig. 4 is a curve plotted by W. B. Newberry from analyses of samples taken every 4 ft. throughout the length of a 6-ft. by 60-ft. kiln. Fig. 5 is a curve plotted from analyses of samples taken from a $5\frac{1}{2}$-ft. and 6-ft. by 160-ft. kiln. This curve shows that the last or upper 50 feet was comparatively useless for this diameter since there was no appreciable chemical change in that part of the kiln.

11 A list of kiln sizes, together with outputs, fuel consumptions, etc., is given in Table 1. It has been observed in practice that the diameter bears a certain relation to the length of the kiln when output and fuel consumption are considered: i.e., a 6-ft. by 60-ft. kiln produces 175 bbl. at 150 lb. coal; a 6-ft. by 100-ft. kiln produces 300 bbl. at 125 lb. coal; while an 8-ft. by 100-ft. kiln will produce 450 to 500 bbl. at 110 to 115 lb. coal. A typical and popular size just now is 8 ft. to 9 ft. by 125 ft. to 130 ft. long. This relation of diameter to length is expressed as follows:

TABLE 1 KILN SIZES, OUTPUTS AND FUEL CONSUMPTIONS

Lining Inches	Diameter Feet	Length Feet	Output Bbl. per day	Fuel Consumption Lb. Coal per Bbl.
6	6	60	175	140–160
6	7	80	300	125–135
6	7	100	375	115–125
9	8	110	550	100–110
9	8	125	600	90–100
9	8	135	675	85– 90
9	8	150	700	80– 85
12	9	150	800	75– 85
12	10	175	1500	70– 80
12	12	200	2000	65– 70

$$L = D \times 16 \text{ (about)}$$

where L = length of kiln in ft. and D = net diameter of kiln in ft.

Actual results secured by lengthening kiln, materials and process remaining unaltered.

Size Ft.	Output Bbl.	Fuel Consumption per bbl., lb.
6 x 60	140	240
6 x 90	200	150

12 *Heat Balance.* The following example will show the method used to determine the distribution of heat in the kiln and the chemical and physical changes taking place during the burning process. The calculations are made for one barrel of cement, taking the actual analyses of raw materials and coal and determining from them the mix or kiln feed.

DATA AND DIMENSIONS

Process	Dry
Size of kiln	8 ft. x 125 ft.
Output of kiln	600 bbl. per day or 25 bbl. per h.r.
Fuel consumption	90 lb. coal per bbl.

Proximate analysis of coal

	per cent
Volatile matter	38.50
Fixed carbon	52.75
Ash	7.50
Sulphur	1.50

B.t.u. per lb. $= (14{,}544 \times 0.5275 + 16{,}515 \text{ x } 0.385) + (354 \times 0.075 - 1635) =$ 12,421 B.t.u.

Area of kiln	3141 sq. ft.
Area of hood	185 sq. ft.
Size of stack	6½ ft. × 125 ft

TEMPERATURES

	deg. fahr.
Air entering kiln from blower	70
Air surrounding kiln (average)	70
Raw mix	60
Clinker discharging from kiln	1400
Waste gases to stack	650
Clinkering zone	2500
Temperature at which gases are liberated	1000

Specific heats

Air	0.2375
Waste gases	0.23
Limestone	0.166
Shale	0.2
Raw mix	0.2
CO_2	0.24
SO_2	0.24

Heats of combination

CaO	954.0 B.t.u. per lb.
MgO	1488.6 B.t.u. per lb.

Heats of decomposition

SO_3	1890 B.t.u. per lb.
$CaCO_3$	765 B.t.u. per lb.

ANALYSES

	per cent Rock	per cent Shale
Ignition Loss	43.34	3.00
SiO_2	1.54	66.20
Fe_2O_3	0.37	5.10
Al_2O_3	0.75	18.50
CaO	53.82	3.00
MgO	0.80	1.50

CALCULATIONS

Shale $(2.8 \times 66.2 + 18.50 \times 1.1 + 5.10 \times 0.7) - (3 + 1.5 \times 1.4) = 204.18 = n$
Rock $(53.82 + 0.8 \times 1.4) - (1.54 \times 2.8) + (0.75 \times 1.1) + (0.37 \times 0.7) = 49.55 = m$

$$\frac{n}{m} = \text{parts rock to one part of shale} = \frac{204.07}{49.55} = 4.12$$

Less 10 per cent for safety........................0.41
Parts rock to one part shale.......................3.71

Rock Shale

Loss......$43.34 \times 3.71 = 160.79 + 3.0 = 163.79$
SiO_2...... $1.54 \times 3.71 = 5.71 + 66.2 = 71.91$
Fe_2O_3.... $0.37 \times 3.71 = 1.37 + 5.1 = 6.47$
Al_2O_3..... $0.75 \times 3.71 = 2.78 + 18.5 = 21.28$
CaO......$53.82 \times 3.71 = 199.67 + 3.0 = 202.67$
MgO..... $0.80 \times 3.71 = 2.97 + 1.5 = 4.47$
470.59

Raw Mix

per cent
Loss.....$163.79 \div 470.59 = 34.80$
SiO_2...... $71.91 \div 470.59 = 15.27$
Fe_2O_3.... $6.47 \div 470.59 = 1.37$
Al_2O_3.... $21.28 \div 470.59 = 4.52$
CaO......$202.67 \div 470.59 = 43.07$
MgO..... $4.47 \div 470.59 = 0.95$
99.98

$100 - 34.8$ loss $= 65.2$ per cent available for cement

Finished Cement

per cent
SiO_2......$15.27 \div 0.652 = 23.40$
Fe_2O_3.... $1.37 \div 0.652 = 2.10$
Al_2O_3..... $4.52 \div 0.652 = 6.93$
CaO......$43.07 \div 0.652 = 66.00$
MgO..... $0.95 \div 0.652 = 1.45$
99.88

Cementation Index

$$\frac{(2.8 \times 23.4) + (1.1 \times 6.93) + (0.7 \times 2.1)}{66 + (1.4 \times 1.45)} = 1.09$$

Hence there is no free lime in the cement made from this mixture.

HEAT BALANCE

HEAT DISTRIBUTION IN KILN PER BBL. OF CEMENT BURNED

a 77.87 per cent $CaCO_3$ to be dissociated

$0.7787 \times 600 = 466.5$ lb. $CaCO_3$

$466.5 \times 765 = 357{,}000$ B.t.u.

b 600 lb. dry raw mix to be heated from 60 deg. to 1000 deg. fahr. (temperature at which gases are liberated)

$600\ (1000 - 60) \times 0.2$ (sp. ht.) $= 112.800$ B.t.u.

c 380 lb. mix heated from 1000 deg. to 2500 deg. fahr. (clinkering temperature)

$380\ (2500 - 1000) \times 0.24$ (sp. ht.) $= 136{,}800$ B.t.u.

d 380 lb. clinker discharged at 1400 deg. fahr. loses by radiation,

$380\ (1400 - 100$ deg.$) \times 0.24$ (sp. ht.) $= 118{,}500$ B.t.u.

e Loss by radiation from shell and hood.

(1) Kiln shell

W = total loss in B.t.u. per sq. ft. per hr.

S = Coefficient of radiation through a rough steel surface = 2.77

T_1 = Average temperature kiln shell = 450 deg. fahr.

T_2 = Average temperature air = 70 deg. fahr.

B = Coefficient of construction = 6

$$W = \frac{125\ S\ (1.0077\ T_1 - 1.0077\ T_2) - 0.55\ B\ (T_1 - T_2)}{76.9}$$

$$= \frac{125 \times 2.77\ (1.0077 \times 450 - 1.0077 \times 70) - 0.55 \times 6\ (450 - 70)}{76.9}$$

= 1738 B.t.u. radiation per sq. ft. per hr. from kiln shell

$3141 \times 1738 = 5{,}549{,}000$ B.t.u. radiation from kiln shell per hr.

Then $\frac{5{,}430{,}000}{25} = 218{,}360$ B.t.u. radiation per bbl. from kiln shell

(2) Hood

Area = 185 sq. ft.

deg. fahr.

Average temperature of hood = 450

Average temperature of air = 70

Difference in temperature = 380

Formula = $185 \times 380 \times 0.74 = 52{,}000$ B.t.u.

2.84 = ratio of increase of radiation for difference in temperature of 380 deg.

Then $2.84 \times 52{,}000 = 147$ B.t.u. radiation per hr. from hood

$\frac{147{,}700}{25} = 5910$ B.t.u.radiation per bbl. from hood

f Heat carried off by CO_2, etc. (temperature escaping to stock 650 deg.)

$208.8\ (650 - 70) \times 0.24$ (sp. ht.) $= 29{,}080$ B.t.u.

g Heat carried off by waste gases

Weight air required to burn 1 lb. coal = 8 lb. (approx.) Assume $1\frac{1}{2}$ times theoretical air supply.

8 × 1.5 = 12 lb. air required to burn 1 lb. coal
12 × 90 = 1080 lb. air required per bbl.
(650 − 70) × 0.23 (sp. ht.) = 133.5 B.t.u. per lb. air
Then the loss per bbl. = 1080 × 133.5 = 144,190 B.t.u.

HEAT DELIVERED TO KILN

a Heat produced by combustion of coal
B.t.u. per lb. coal assuming 1.5 times theoretical air supply = 12,421 B.t.u.
8 × 1.5 = 12 lb. air per lb. coal
12 − 8 = 4 lb. air excess
4 (650 − 70) × 0.2375 (sp. ht.) = 550 B.t.u. absorbed per lb. coal by excess air
Then 12,421 − 550 = 11,871 B.t.u. per lb. coal available
90 × 11,871 = 1,068,390 B.t.u. total heat of combustion

b Heat received due to cooling of gases (CO_2 etc.) from 1000 deg. to 650 deg. fahr.
0.348 × 600 = 208.8 lb. CO_2, etc.
208.8 (1000 − 650) × 0.24 (sp. ht.) = 17,520 B.t.u.

c Heat liberated by chemical reaction
0.66 × 380 = 251 lb. CaO per bbl.
251 × 954 = 239,434 B.t.u.
0.0145 × 380 = 5.51 lb. MgO per bbl.
5.57 × 1489 = 8204.39 B.t.u.

d Heat carried into kiln through blow pipe
1080 lb. air required per bbl.
1080 × (70 − 32) × 0.2375 (sp. ht.) = 9750 B.t.u.

SUMMARY

Heat distribution in kiln

	B.t.u. per bbl.	per cent
a Dissociation of carbonates	357,000	26.6
b Heating 600 lb. dry raw mix from 60 deg. to 1000 deg. fahr.	112,800	8.26
c Heating 380 lb. mix from 1000 deg. to 2500 deg. fahr.	136,800	10.00
d Loss through radiation from discharged clinker	118,500	8.8
e Radiation from shell and hood	224,270	16.8
f Carried off by gases (CO_2 etc.)	29,040	2.16
g Carried off by waste gases	144,190	10.70
Total	1,122,640	83.32
Received by kiln	1,341,322	......
Difference unaccounted for (probably radiation)	218,682	16.45
Total	....	99.77

Heat received by kiln

	B.t.u. per bbl.	per cent
a Combustion of coal	1,068,390	79.65
b From cooling gases	17,520	1.30
c Liberated by chemical reactions	247,662	18.46
d Delivered through air pipe	9,750	0.72
Total	1,341,322	100.13

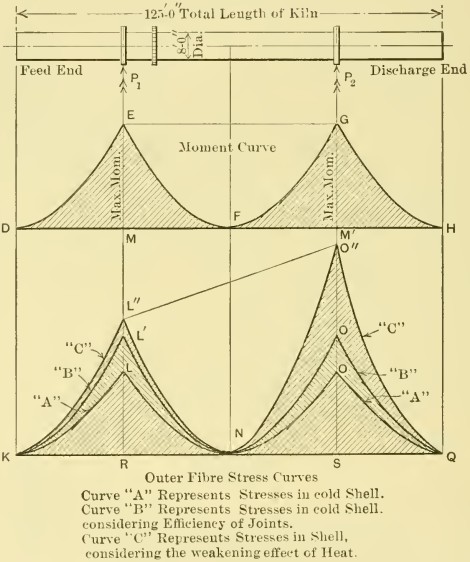

125'-0" Total Length of Kiln
8'-0" Dia.
Feed End
Discharge End
P1
P2
E
G
Moment Curve
Max. Mom.
Max. Mom.
D
F
H
M
M'
O''
L''
L'
"C"
"B"
"A"
L
O'
"C"
O
"B"
"A"
N
K
R
S
Q
Outer Fibre Stress Curves
Curve "A" Represents Stresses in cold Shell.
Curve "B" Represents Stresses in cold Shell.
considering Efficiency of Joints.
Curve "C" Represents Stresses in Shell,
considering the weakening effect of Heat.

Fig. 6 Stress Diagram for an 8-ft. by 125-ft. Rotary Kiln with Improper Tire Spacing

From the foregoing summary, it will be noticed that only 44 per cent of the heat delivered to the kiln is theoretically required, the balance being lost through radiation, carried off by waste gases, etc.

13 *Design.* In designing a kiln it is necessary to take into consideration the weakening effect of the heat upon the strength of the steel. For this reason it is necessary so to space the riding tires or supports that the outer fiber stresses at points of maximum bend-

ing moments will be nearly equal after considering the weakening effect of the heat and the joint efficiences. Fig. 6 illustrates the effect of improper spacing of tires. This kiln, the exact duplicate of the one in Fig. 8, will carry a load only one-half as great, assuming the same factors of safety, due to the location of the points of support.

14 Were it not for the presence of heat, the design of a kiln would be comparatively simple, as riding tires could be placed as closely as desired. Fig. 7 illustrates an 8-ft. by 125-ft. kiln on three supports and the bending-moment curve when *all three* tires are touching the carrying rollers and when *only two* are touching. In operating a kiln it is very often necessary to stop its rotation for a few seconds or minutes and the intense heat gives the kiln a permanent "set." Assuming the carrying rollers to be in proper alignment, there is a portion of the revolution when the kiln is riding on *only two* tires. This obviously increases the bending moment and the outer fiber stress beyond the limits of safety, which inevitably results in the shearing of rivets or the tearing of plates. Fig. 8 illus-

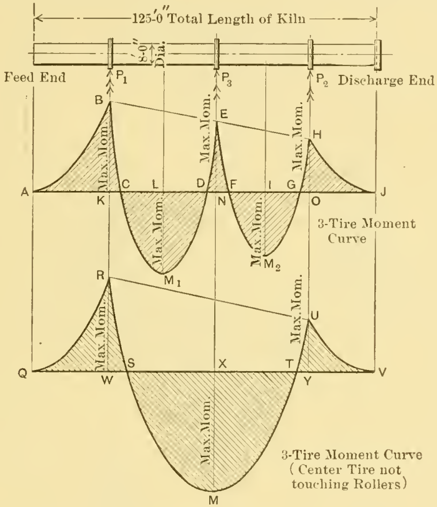


FIG. 7 STRESS DIAGRAM FOR AN 8-FT. BY 125-FT. ROTARY KILN WITH THREE SUPPORTS

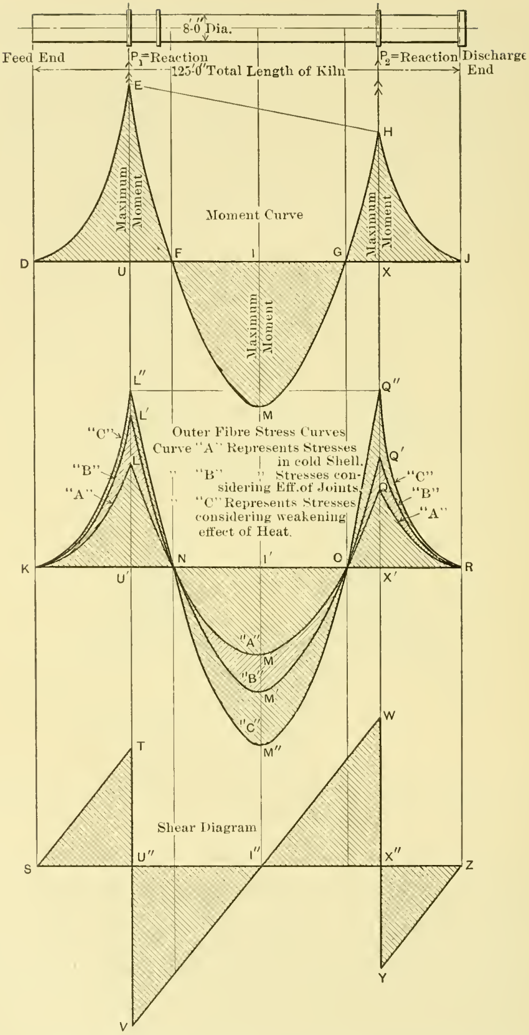

8'-0" Dia.
Feed End
P1=Reaction
125'-0" Total Length of Kiln
P2=Reaction
Discharge End
E
H
Maximum Moment
Moment Curve
Maximum Moment
D
U
F
I
G
X
J
Maximum Moment
L''
L'
L
M
Q''
Q'
Q
"C"
"B"
"A"
Outer Fibre Stress Curves
Curve "A" Represents Stresses in cold Shell.
" "B" " Stresses considering Eff. of Joints.
" "C" Represents Stresses considering weakening effect of Heat.
"C"
"B"
"A"
K
N
I'
O
R
U'
X'
"A"
M
"B"
M'
"C"
M''
T
W
Shear Diagram
S
U''
I''
X''
Z
Y
V

FIG. 8 STRESS DIAGRAM FOR AN 8-FT. BY 125-FT. ROTARY KILN WITH PROPER TIRE SPACING

trates an 8-ft. by 125-ft. kiln with tires properly spaced and the outer fiber-stress curves plotted. Curve *A* represents stresses in the cold shell; curve *B*, stresses after considering the efficiency of riveted joints; curve *C*, stresses considering the weakening effect of the heat. In this latter curve, the stresses *U′-L″*, *I′-M″*, and *X′-Q″* should be practically equal.

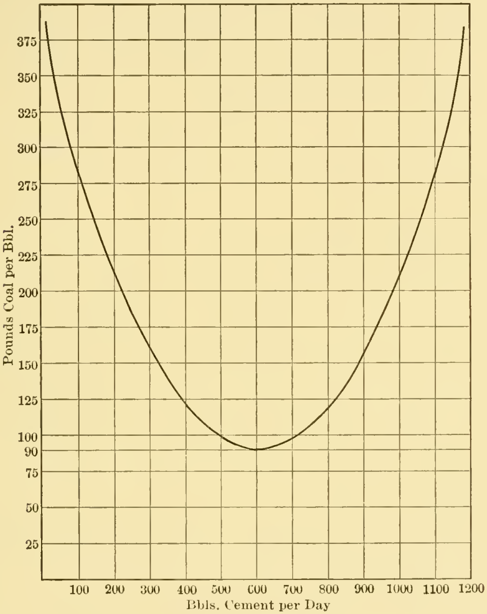


FIG. 9 FUEL CONSUMPTION CURVE

15 *The Law of Pivotal Points.* In the following paragraph an endeavor is made to apply to the rotary kiln the natural law known as the Law of Diminishing Returns or the Law of Pivotal Points. With given conditions as to materials, fuel, size of kiln and other important considerations, there is a certain production in barrels per day where the fuel consumption is a minimum. Conditions, materials and other features vary so much in different locations that it is

extremely difficult to make a definite statement as to this Law of Pivotal Points for each size of kiln. In Fig. 9 is plotted the curve for an 8-ft. by 125-ft. kiln, operating upon average limestone and shale by the dry process.

16 To illustrate, if this kiln is producing 300 bbl. per day, the fuel consumption is 160 lb. per bbl.; at 400 bbl. the fuel used is 120 lb.; and the point of economical fuel consumption is 90 lb. per bbl., at which point the output is 600 bbl. per day. Beyond this production the fuel consumption increases until the kiln is literally choked.

The author hopes to be able to present more extensive information along this line in the near future.

AUTOMATIC CONTROL OF CONDENSING WATER

By B. Viola, Brooklyn, N. Y.

Member of the Society

Condensers for vacuum plants, to which this paper is chiefly devoted, employ the wet system of condensation, in which the cooling surface is that of the cooling water during its progress through the condenser.

2 In practice it is often found that the injection of cooling water is unnecessarily increased at times by incorrect operation of the condensing plant. Beside other visible indications of this mistake the temperature of the condensed water shows it most strikingly. When too much water is used the work of the air pump is made more difficult because of the air liberated from the water and if the pump is accurately proportioned for normal operation it is unable to accomplish the extra work. If the pump is large enough, the work is accomplished, but at the expense of additional steam. If a wet air pump is employed it is called upon to remove an excess of both air and water. Moreover, the excessive injection of water causes a higher pressure in the condenser. Assuming the falling water to be a liquid cylinder, the outer surface of this cylinder upon entering the hot steam takes up the heat of the steam, while the interior parts remain cooler. If, owing to the great velocity of the fall, the water column is unable to effect cooling by the interior portions of the water as well as by the exterior surface, the heat of the discharged water will be too low. But if the equalization of temperature can be brought about through the whole water cylinder during this fall the cooling power of the water can be utilized more completely.

3 The more finely the water can be divided in falling the more readily will the gases pass through it and the resistance will be diminished as the surface is increased. The division of the water

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brings about to a great extent the escape of the air contained in the cooling water. This division, however, is never fine enough; hence in counter-current condensers the real counter flow takes place only upon the surface of contact between water and steam.

4 Proper utilization of the cooling surface can only be provided for by a proper arrangement of the time of contact. For a freely falling body the time of falling with reference to the height of the fall is

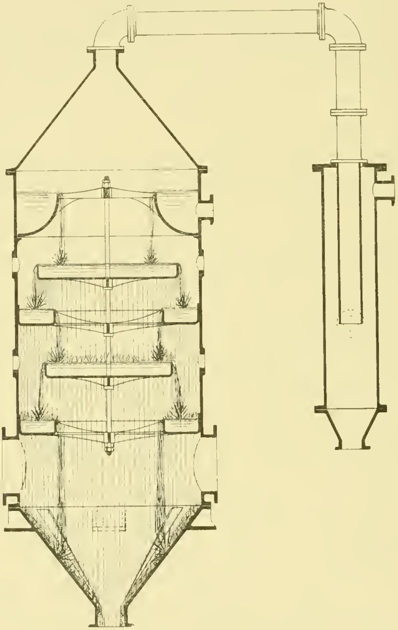

Fig. 1 Concentric Counter-Current Condenser

$$t_{\mathrm{h}} = \frac{v}{g} = \frac{\sqrt{2gh}}{g} = \sqrt{\frac{2}{g}} \times \sqrt{h}$$

Theoretically, therefore, the time increases as the square root of the height of the fall, but in the condenser the resistance increases with the height of the fall. Dividing the height of the fall into n parts, we have $h = n\frac{h}{n}$. Giving to the resistance the smallest value possible and to the time of heat transfer in the condenser the highest value, the limit of the time of contact of water and heat will be

$$t_{\left(n\frac{h}{n}\right)} = n\sqrt{\frac{2}{g}} \times \sqrt{\frac{h}{n}} = \sqrt{\frac{2}{g}} \times \sqrt{nh}$$

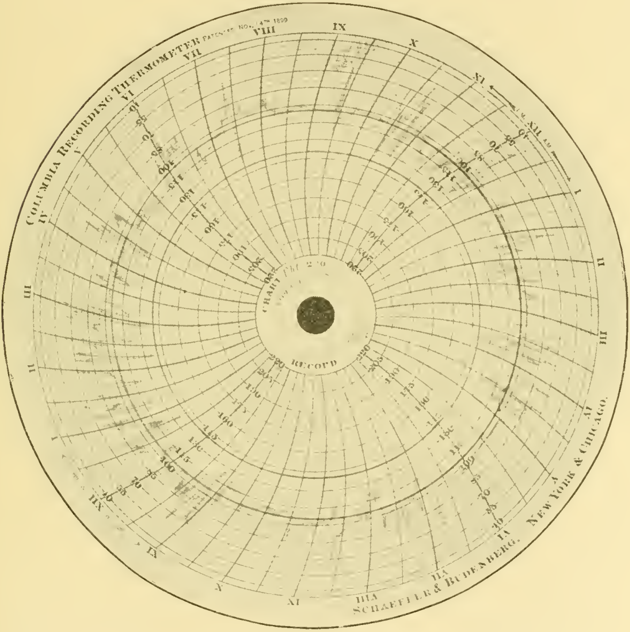

FIG. 2 AUTOGRAPHIC CHART SHOWING VARIATIONS IN TEMPERATURE UNDER HAND REGULATION

Then for every value where $n > 1$, we have $t_{\left(n\frac{h}{n}\right)} > t_h$

and in general $t_{\left(n\frac{h}{n}\right)} = \sqrt{n}\,t_h$. If n be taken very large and $\frac{h}{n}$ very small, the time of contact between steam and water in the condenser will be extended proportionately since

$$\frac{h}{n}=\frac{gt^2}{2n^2}$$

5 It is necessary, however, that the partial fall $\frac{h}{n}$ be not less than the value required by the amount of steam to be condensed. From this calculation it is seen that the velocity of the water is governed by the height of fall and it is advisable to restrict this height in order to prevent friction resistance, if for no other reason. The smallest value of friction resistance is at $h=0$, corresponding to the condition when steam and gases flow over standing water. Plants

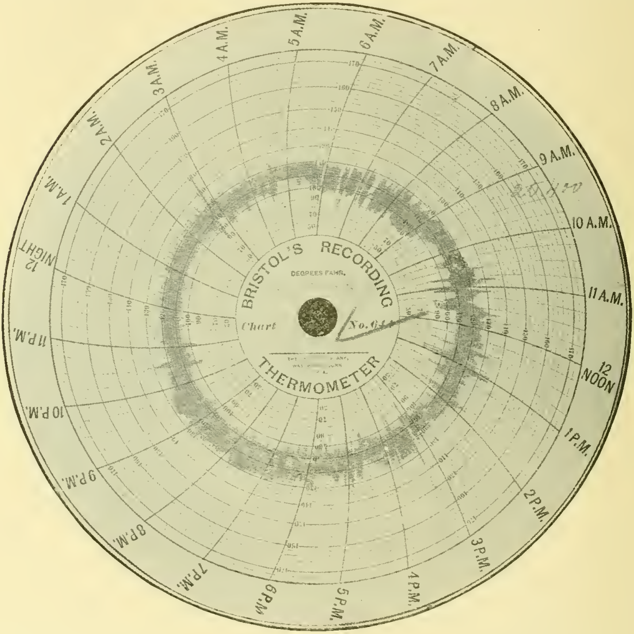

Fig. 3 Autographic Chart Showing Variations in Temperature with Automatic Regulations

of such construction, however, would be too large. Moreover, water and gases being poor heat conductors when in a state of rest, it is necessary to provide for a certain degree of motion for water in a condenser.

6 Further, the quantity of steam condensed per unit of time is directly proportional to the cooling surface and a division of the cooling water is therefore equivalent to an extension of the cooling surface.

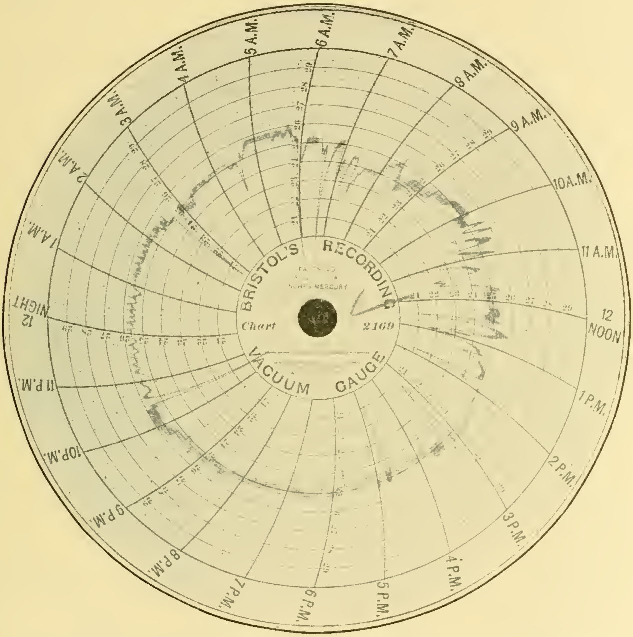

Fig. 4 Autographic Chart Showing Variations in Vacuum with Automatic Regulation

7 Therefore, to heat condensed water quickly to the necessary temperature by direct contact with the steam, it is necessary (*a*) that the surface of the cooling water be large, (*b*) that the cooling surface change quickly, and (*c*) that the time of contact between steam and water be as long as possible.

8 To fulfill these conditions a concentric counter-current condenser such as that shown in Fig. 1 gives the best results. This condenser is designed for use in connection with two or more vacuum pans. By the addition of basins or trays the duration of the contact between water and steam is raised in the ratio of $\sqrt{n}$, resulting in an economy of water. Some water will accumulate in each of these trays temporarily and the temperature is therefore equalized at each stage.. The fresh supply of water will sink to the bottom of the tray, forcing the lower stratum upward on account of the difference in temperature, and the warmer water will flow over from one tray to the next. The trays in this manner form zones with the desired small difference of temperature and constitute a graduated scale from the temperature of the steam admission tothat of the gas outlet. The surface of condensation depends primarily on the size of the cooling-water cylinder when the depth of the trays is greater that zero. It may even be said that these moving water columns promote the cooling and air and gases will pass at the surface of the trays even though they do not pass at the bottom. During the time the water remains in the trays it has a chance to take up more heat, which is withdrawn from the steam. It is very important that enough water be permitted to flow to secure good results, but by providing the trays with spray holes, the cooling effect of the water is considerably increased.

9 The work of the condenser varies with temperature, but in general it performs about 610 times the work of the air pump, volumetrically speaking. It is absolutely necessary to exhaust the air and gases to promote condensation, but the best air pump cannot do good work with a poor condenser, while a good condenser accomplishes at least fair results with an indifferent air pump.

10 It is very important that the right quantity of water be used to condense a certain quantity of steam. This matter is neglected in most condensing plants and some kind of automatic device should be applied to regulate the flow of cooling water. Experience has shown that the amount of water should be from 20 to 40 times that of the steam to be condensed. This is a very wide limit and in large condensing plants where immense quantities of cooling water are required some controlling device should be applied from an economical standpoint, so that water will not be wasted.

11 The first step is to decide at what temperature the water should be discharged from the condenser. This, of course, bears a certain relation to the steam to be condensed. The description

which follows is a record of experiments made and results achieved with a condensing plant used in connection with vacuum pans. I first applied a recording theremometer in the tail pipe of a concentric barometric condenser for the purpose of controlling the cooling water by hand operation of the inlet valve; but it was very difficult to convince the operator of the condenser that it was not necessary to let the cooling water run off cold, because it is generally believed the colder the water the higher the vacuum. The variations in temperature under hand control can be seen in Fig. 2. After experimenting for some time it was found very difficult to secure good results by hand regulation because of the continuous changes which must be made to meet conditions as the number of pans connected to the condenser is increased or decreased. This led to the application of an automatic temperature controller in the tail pipe connected to the compressed-air inlet valve, by which it was found possible to feed the condenser approximately in proportion to the steam or vapor which had to be condensed, resulting in a better average temperature of the condensed water and only slight variations.

12 The temperature of the condensed water at a given time may be compared with the corresponding vacuum secured by automatic regulation from Figs. 3 and 4. By maintaining a nearly equal temperature of the condensed water, a very uniform vacuum was obtained except at periods when a new vacuum pan was charged. The most striking changes will be noticed at 10.30 p.m., 2.45 a.m. and 6 a.m. in Fig. 4. At the same periods the controlling thermometer shows a considerable fall in temperature, due solely to the temperature of the air drawn in from a newly charged pan which was filled with air at the temperature of the operating room. The vacuum pump draws it into the condenser, as a consequence of which the vacuum drops until all the air is drawn out and the new pan reaches an equilibrium with the vacuum the pump is able to keep up in connection with the other pans. During this period of low vacuum the water is shut off by the controlling thermometer and no cooling water whatever enters the condenser. Since the other pans are boiling, the temperature in the condenser increases until the water left in the trays is raised to the temperature limit, when the controlling thermometer opens the inlet valve and the cooling water is again admitted.

13 The fact that the higher vacuum is not obtained with an excess of cooling water can be seen from Figs. 3 and 4. Between 4.45 and 5.15 a.m., when according to the chart the lowest temperature was

110 deg. and the highest 120 deg., the corresponding vacuum was 25.8 in. The charts shown in Figs. 5 and 6 show even higher vacuums with a temperature of 120 deg., the same vacuum pump and the same number of vacuum pans being used in each case.

14 The construction and operation of the automatic controlling device by which the foregoing results were obtained is shown in Fig. 7. The stem *B* expands and contracts in response to temperature changes of the condensed water. The pipe *E* supplies compressed air of about 15 lb. pressure to the valve mechanism of the controller, from which it passes through pipe *G* to the water-inlet valve, where it actuates a regular globe valve *D* by means of a diaphragm motor which

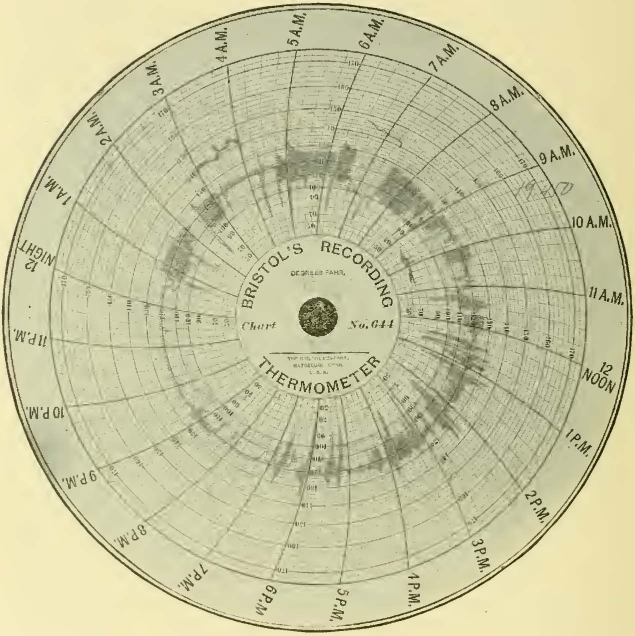

Fig. 5 Autographic Chart Showing Variations in Temperature with Automatic Regulation

replaces the ordinary hand wheel. The temperature of the condensed water affecting the stem of the controller permits all, a part, or none of the compressed air to pass to the diaphragm-motor valve and consequently the latter is very nearly closed, partly open, or wide open according to the conditions prevailing, allowing the proper flow of water to the condenser.

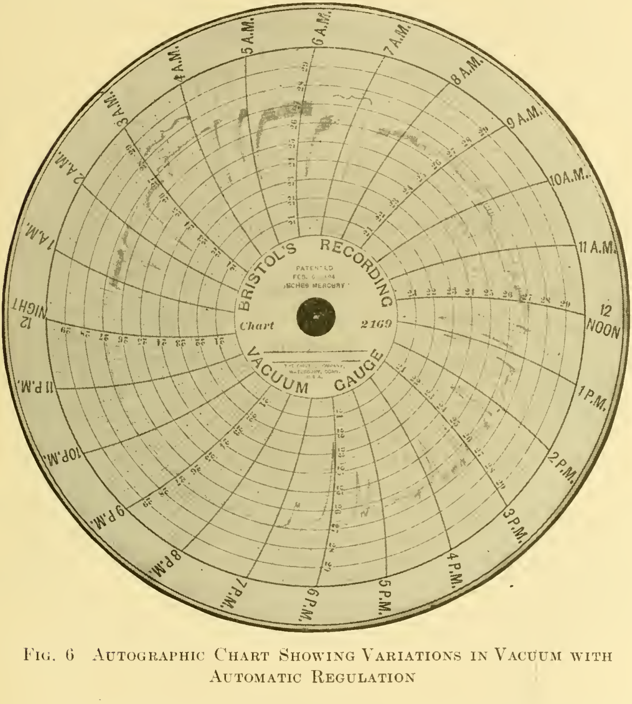

Fig. 6 Autographic Chart Showing Variations in Vacuum with Automatic Regulation

15 Let us assume that the vapor pipe has been delivering an amount of vapor to the condenser which requires an amount of water that will flow through the inlet valve when the latter is exactly half open. Should more vapor enter the condenser, however, the temperature of the water passing through the tail pipe would, of course, start to rise, but as soon as the controller stem was affected by this higher temperature it would expand and cause the valve mechanism of the

controller to allow less air to flow to the water-inlet valve. Consequently this water valve would act to allow more water to pass through and thus maintain the proper proportion between the volumes of vapor and cooling water. The auxiliaries are, *J*, a thermometer to indicate the temperature of the cooling water; *F*, a hand valve for emergency use; *C*, a thermometer to indicate the temperature of the water passing through the tail-pipe and serving as a check on the recording

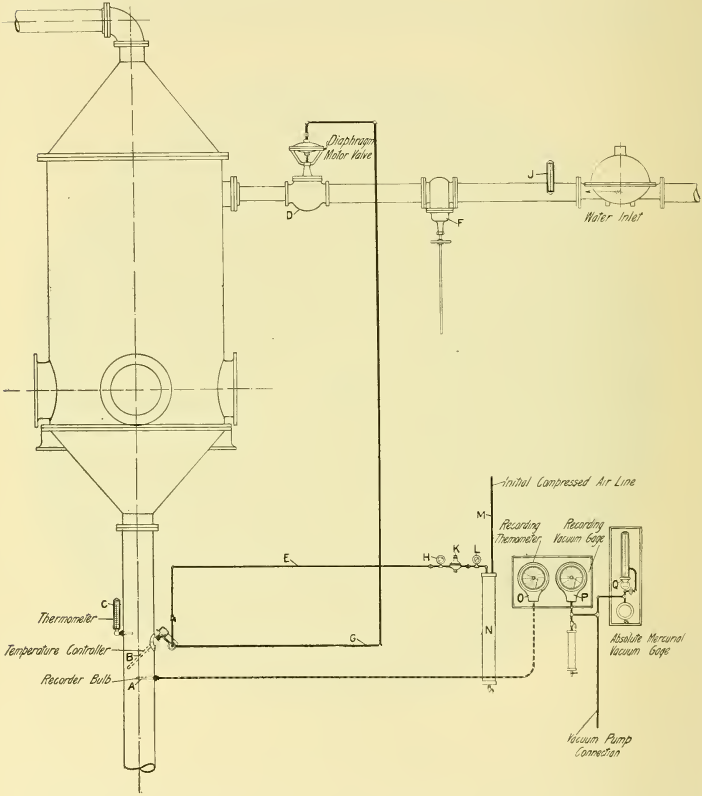

FIG. 7 DIAGRAM OF AUTOMATIC CONDENSING WATER CONTROL

thermometer, which has its bulb at *A* and its dial at *O*; and *P*, a recording vacuum gage, checked by a mercurial absolute-pressure gage, *Q*. The initial supply of compressed air, *M*, which ultimately operates the diaphragm-motor valve on the water inlet, enters the trap *N*, where any moisture or sediment is separated and which also acts as a storage reservoir. Gage *L* shows the initial pressure of the compressed air supply, which is reduced by passing through reducing valve *K* to the pressure required for the controller, as shown by gage *H*.

16 Fig. 8 shows the very simple construction of the controller by means of a section through *A-B*. The stem *S* is in two parts, the outer brass tube and the inner rod. The latter is composed of a material which has an extremely low ratio of expansion and therefore remains of almost constant length, regardless of temperature, while the outer brass tube elongates or contracts in response to temperature changes. The tube and rod are so arranged that they are always in intimate though frictionless contact at the extreme end. *R* shows the extension of the inner non-expanding member, which recedes when the outer tube elongates and advances when the outer tube contracts.

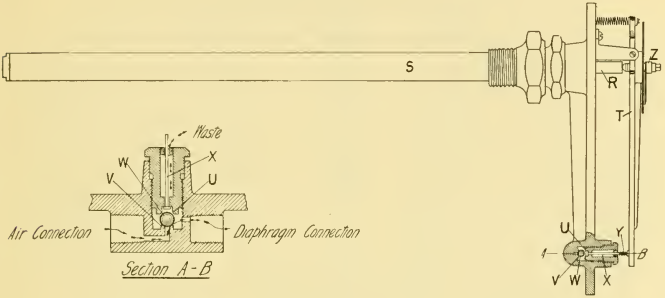

FIG. 8 CONSTRUCTION OF AUTOMATIC CONTROLLER

17 The movement thus obtained at *R* is transmitted by the lever *T* to the valve mechanism shown in cross section. This is simply a three-port valve, shown more clearly in the section *A-B*, and all ports are controlled by the one ball *W*. The first port, *V*, is the inlet for the compressed air supply; another port, the second, connects with the line leading to the diaphragm-motor valve; the third port is the outlet for the air which has served its purpose by actuating the diaphragm-motor. The position of the ball *W* depends upon the stem

X, which is in contact with the lever *T* at *Y*. When extension *R* moves outward due to the drop in temperature at *S*, the lever *T* is raised, and the stem *X* allows the ball *W* to leave port *V* where the compressed air enters. The air can then flow through the second port to the diaphragm-motor valve, which starts to close. If a higher temperature acts upon *S*, expanding the outer tube and turning extension *R* inward, lever *T* forces stem *X* against ball *W*. The latter then closes port *V*, shuts off the air supply, and also opens the third port so that the air can escape from the diaphragm motor. The diaphragm-motor valve consequently begins to open.

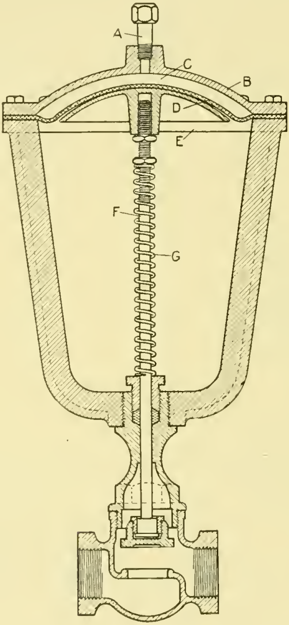

Fig. 9 Section Through Diaphragm-Motor Valve

18 In actual practice, the diaphragm-motor valve is only completely closed or wide open if the conditions are such that the tendency is toward a sudden change in temperature. The controller is so sensitive that the diaphragm-motor valve is constantly throttling,

that is, letting in just a little more or a little less water as may be required properly to effect the condensation.

19 If it is desired to change the setting of the controller, to maintain a higher or a lower temperature, it is necessary simply to apply a key to the port *Z* and by turning it one way or the other require extension *R* to travel more or less before the controller operates.

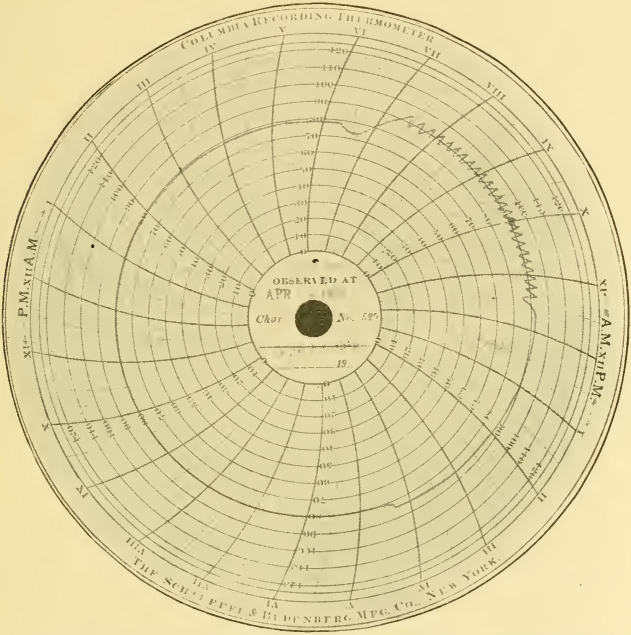

Fig. 10 Autographic Chart Showing Automatic Temperature Regulation of a Surface Condenser

20 Fig. 9 shows the diaphragm-motor valve in section. This valve has a regular globe body, with a seat and disc arranged in the usual manner, but with a sliding stem that is operated by the diaphragm motor. The compressed air enters chamber *C* at opening *A*. This chamber is composed of a cast-iron top *B* and a rubber bottom *D*, called the diaphragm. The air pressure forces the diaphragm down-

ward and the saucer E thus forces the stem F downward while compressing the spring G. When the air pressure is relieved the spring opens the valve again.

21 This installation has been the means of saving about $400 monthly for over a year in the charges for city water which was formerly wasted.

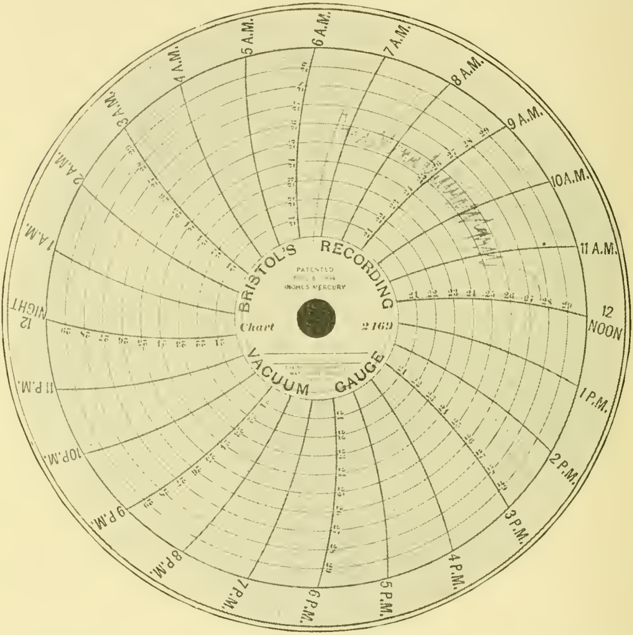

Fig. 11 Autographic Chart Showing Automatic Vacuum Regulation of a Surface Condenser

22 In Figs. 10 and 11 are shown autographic charts taken from a temperature controller and applied to a single surface condenser connected to a vacuum drier. With this installation very good results have been obtained and the quantity of cooling water has been decreased from 35 to 50 per cent over that required with hand regulation.

23 The question arises as to whether, with an equipment as described above, it is possible to attain a cooling-water rate near enough to that called for by theoretical formulae to be economical. Records of the water consumption as determined by meter readings show results very close to theoretical and indicate great savings over the water required with former conditions of operation.

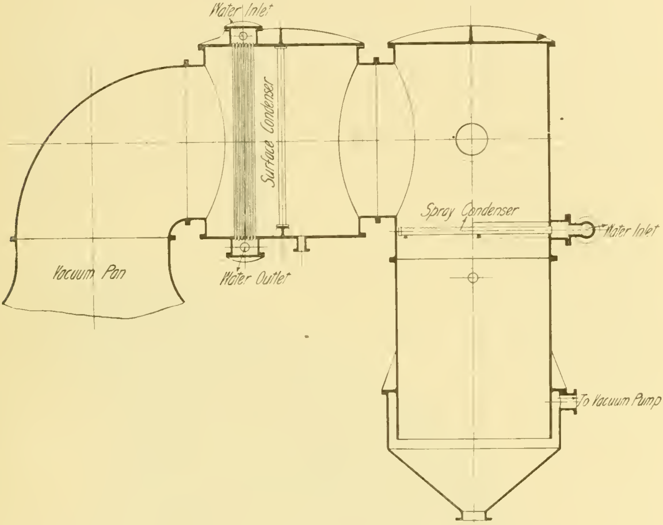

Fig. 12 Combined Surface and Spray Condenser as Applied to a Vacuum Pan

24 In sugar refineries, combined surface and spray condensers are usually employed which are similar to that shown in Fig. 12. The vapor from the vacuum pan passes the surface condenser first for the reason that in case the vapor carries along some sugar particles, they will be condensed at that point and can be used to dissolve the raw sugar. In this way nothing is lost. The remainder of the vapor passes to the spray condenser, is condensed and flows down the tail-pipe.

25 Condensers of this type require a considerable quantity of water and permit of great waste when no controlling device is employed.

Even where salt water is used this waste should not be permitted because it increases materially the quantity of steam necessary for the operation of the pumps. In many cases where salt water is now used on account of the great quantity required, the use of a well-constructed counter-current condenser operated economically with a precise temperature controller may make possible the use of sweet water. This is a decided advantage where the condensed water can be used for boiler-feed purposes. I would not recommend its use in the same condition as when it flows from the tail-pipe, in spite of the assertion that condensed water does not contain any impurities carried over from the source of the vapor. In steam engine plants for instance, it is well known that condensed steam contains oil, etc., and it is never pumped direct to the boilers. It has been determined from frequent analysis that condensed water from vacuum plants does not contain sugar or acid from the evaporation of acid liquor, but the so-called untraceable losses in vacuum plants must necessarily be looked for in the condensed water. The quantity of water used is so great that the presence of these impurities is not noticeable, but practical experience has proved them to be present. However, when this condensed water at a high temperature (110 to 120 deg.) is passed through an efficient water-purifying plant, there is no doubt that it may safely be used for boiler feed.

THE UNITED STATES BATTLESHIP NORTH DAKOTA

At a joint meeting of a number of engineering societies in and about Boston, held at the Hotel Somerset in that city on Friday evening, January 21, 1910, C. B. Edwards, chief engineer of the Fore River Shipbuilding Company, gave an illustrated lecture descriptive of the battleship North Dakota, which was at that time the latest addition to the United States Navy, and which was dedesigned and constructed under the direction of Mr. Edwards.

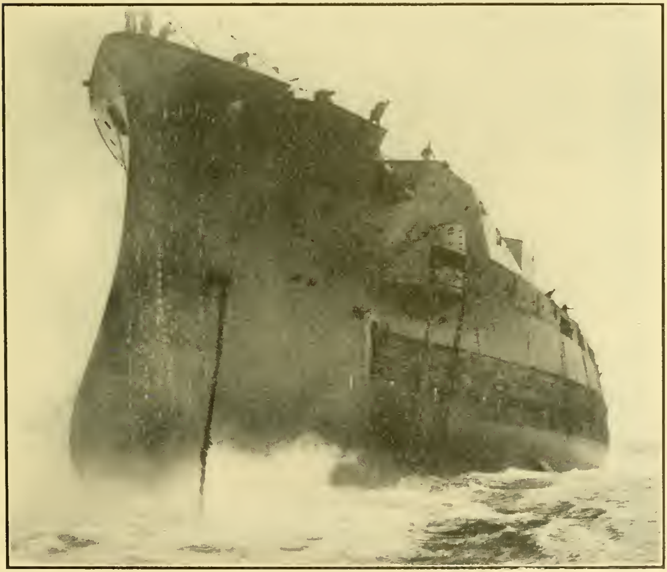

FIG. 1 LAUNCHING OF THE U. S. BATTLESHIP NORTH DAKOTA, NOVEMBER 10, 1908

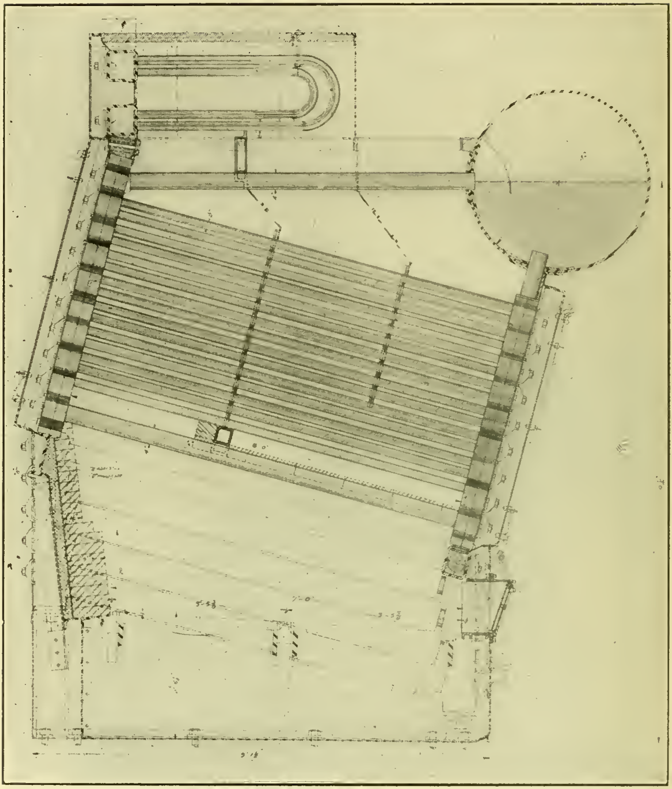

Fig. 2 Sectional View of Babcock and Wilcox Boilers

These boilers are fitted with superheaters for the use of oil fuel in conjunction with coal. Grate surface, 1439 sq. ft.; heating surface, 55,800 sq. ft.; superheat surface, 6194 sq. ft.

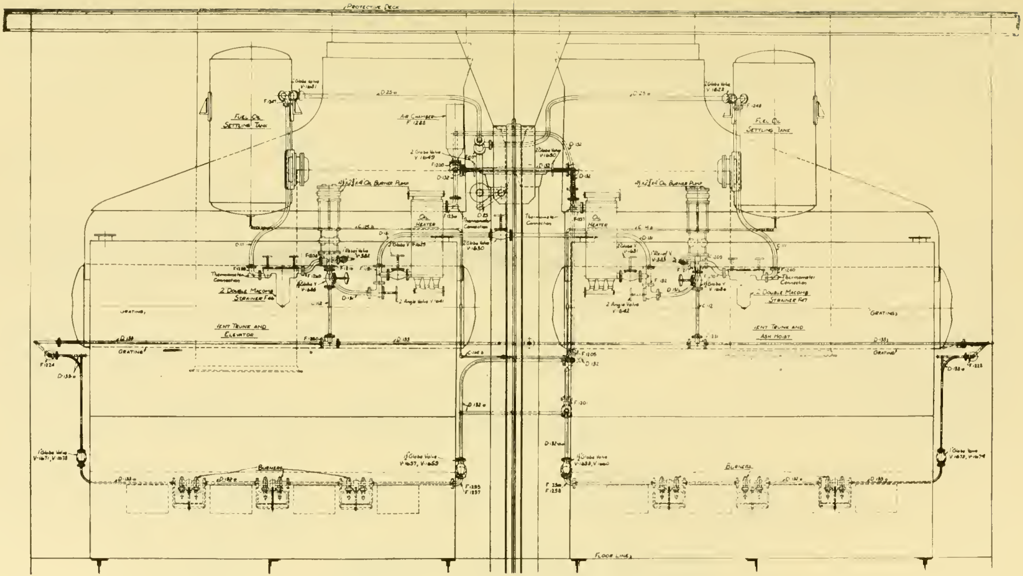

FIG. 3 SECTION THROUGH FIRE ROOM

This view shows the fuel oil arrangement of Schutte-Koerting type. The oil is injected into the furnace under a pressure of 150 lb. per sq. in. and at a temperature of 250 deg. over the top of the coal fire. This facilitates the raising of steam and the fuel oil carried in the inner bottom increases the cruising radius of the vessel.

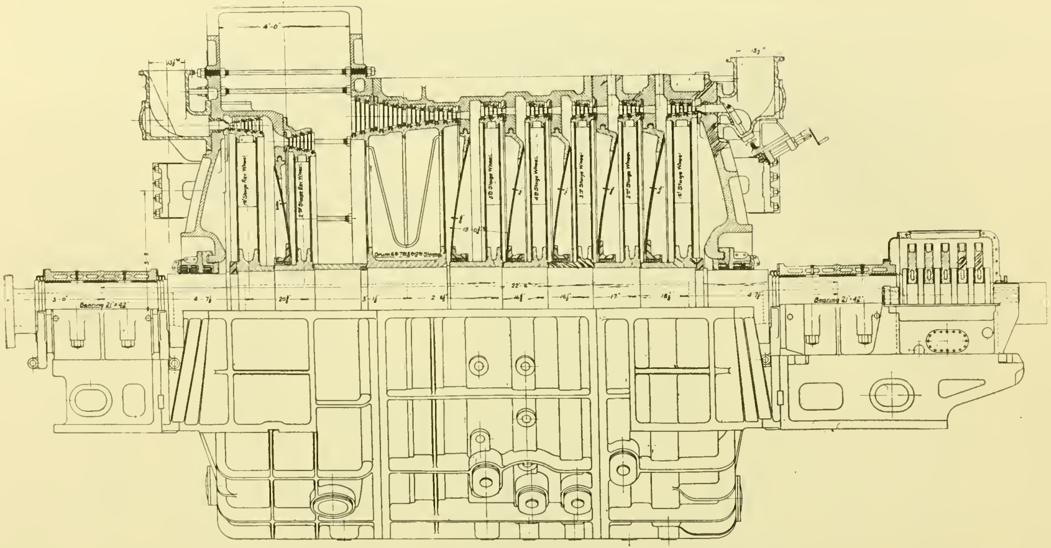

FIG. 4 SECTIONAL VIEW OF ONE OF THE MAIN TURBINES

It will be observed that this turbine is arranged for both ahead and astern power in one shell, or casing, with a common exhaust connection. For ahead motion, steam is admitted at the forward end just above the thrust bearing and passes through nine pressure stages. The rotating buckets of the first five stages are attached to the periphery of their respective wheels, while the last four are mounted upon a drum which is so proportioned that the steam pressure balances a portion of the thrust exerted by the propeller, the thrust block taking the remainder. For astern motion, steam is admitted to the after end of the turbine and passes through two turbine stages to the exhaust.

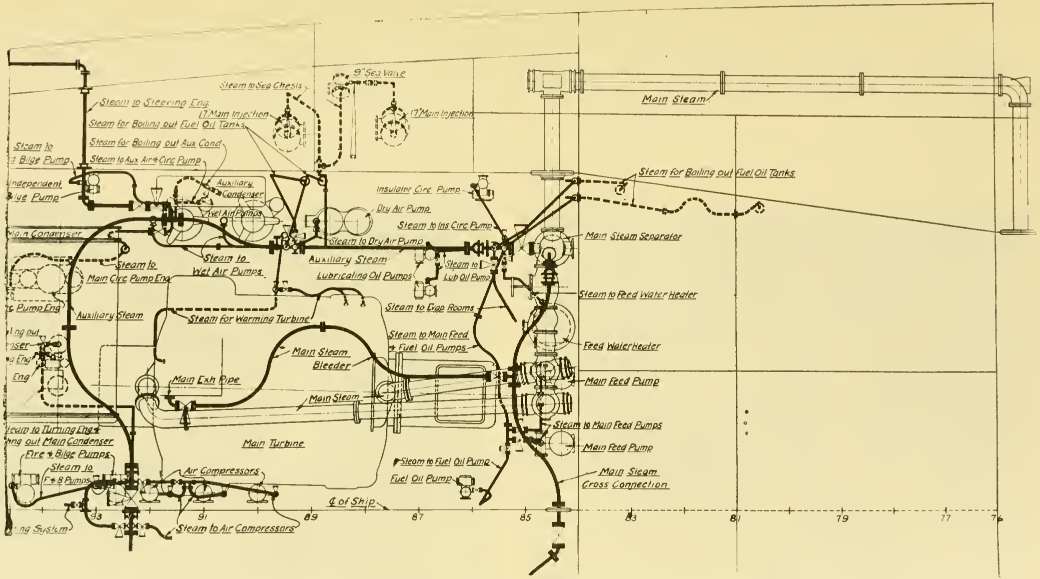

FIG. 5 PLAN VIEW OF ONE OF THE ENGINE ROOMS

The engine rooms are located directly opposite and just forward of the magazine, making it necessary to carry the main steam pipes from the boiler room around the magazine. Each engine room measures approximately 44 ft. by 25 ft. by 25½ ft., and in this contracted space about 35,000 h.p. has been obtained from the main machinery alone.

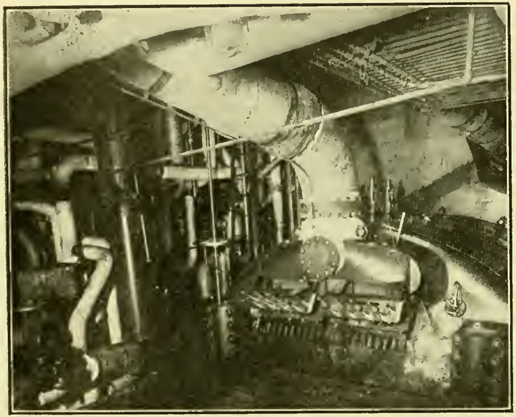

FIG. 6 FORWARD END OF ONE OF THE TURBNES

This view is taken looking aft from the working platform in the forward part of the engine room and shows the forward end of one of the main turbines, together with the main steam and exhaust pipes. In the background may be seen some of the auxiliary piping, which presents a somewhat congested appearance.

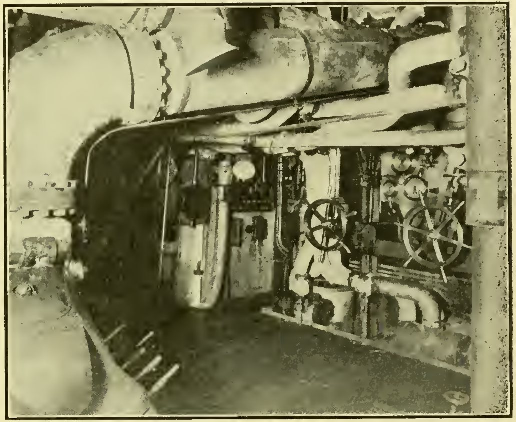

FIG. 7 WORKING PLATFORM FORWARD OF ONE OF THE TURBINES

This view is taken in the opposite direction to that of Fig.4 and shows the hand wheels for operating ahead and astern throttle valves, together with the mechanical telegraphs, telephone connections, gages, ventilating system, etc.

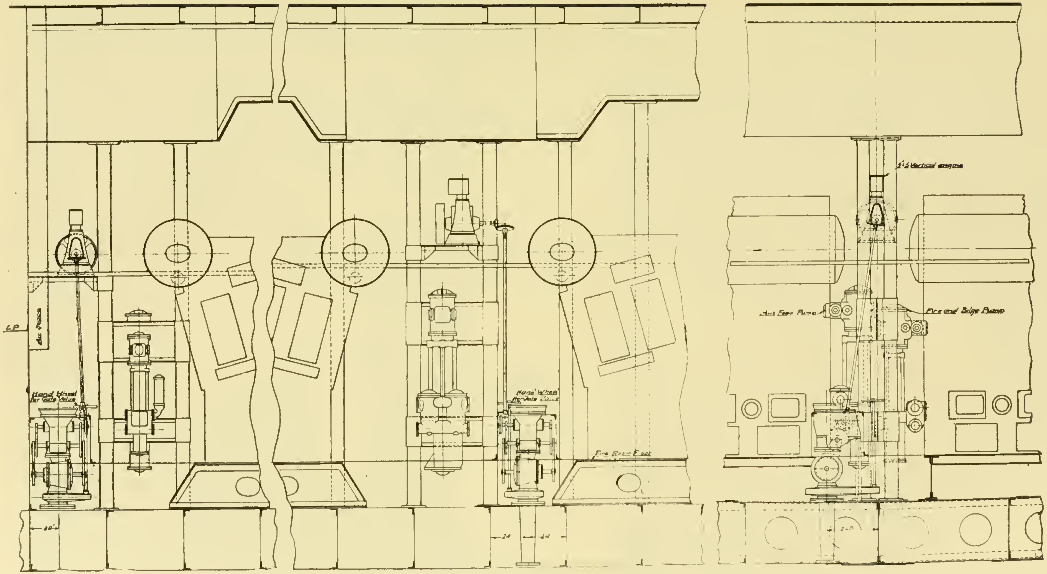

FIG. 8 ASH EXPELLER MECHANISM

This is a new departure in naval engineering by which the ashes are discharged through the bottom of the ship. They are put through a crusher and expelled by means of compressed air at 95 lb. pressure.

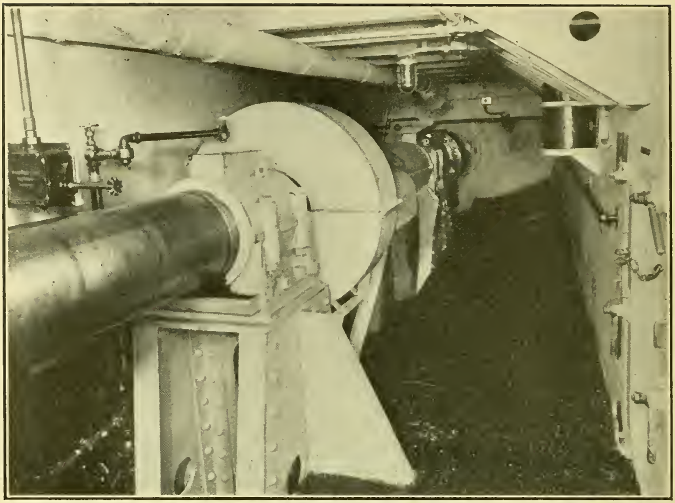

FIG. 9 TORSION METER FOR MEASURING TWIST OF SHAFT AND HORSEPOWER TRANSMITTED

The shaft is 14 in. in diameter with an 8-in. bore. The twist is about one degree in a length of 8 ft. when transmitting full power.

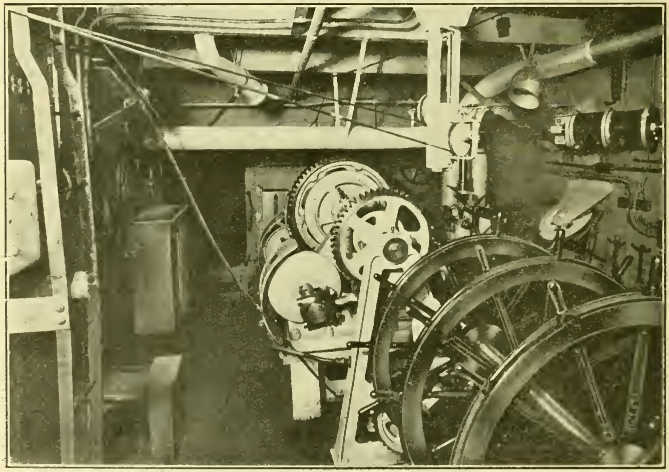

FIG. 10 STEERING-ENGINE ROOM

Wire ropes transmit the motion from the wheels on the bridge and in the conning towers to the drums for operating the steam steering gear. The large wheels provide means for steering by hand.

A number of the lantern slides used to illustrate Mr. Edwards' lecture are reproduced herewith, together with descriptive captions taken from his remarks as the pictures were thrown on the screen.

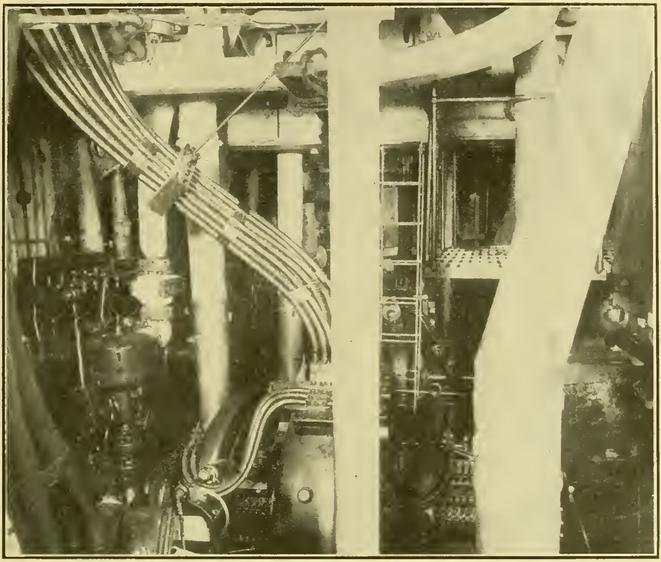

FIG. 11 THE DYNAMO ROOM

Four 300-kw. turbo-generating sets are crowded into a space of about 20 ft. by 42 ft.

The North Dakota is 518 ft. in length and 85 ft. in width, and has a draft of 26 ft. 10$\frac{3}{4}$ in. She has a normal displacement of 20,000 tons and contains approximately 1950 tons of machinery. There are 431 watertight compartments, not including the inner bottom, besides many other compartments which are non-watertight. Practically all of the auxiliary machinery was tested under approximately normal operating conditions, and the water rates established before installation.

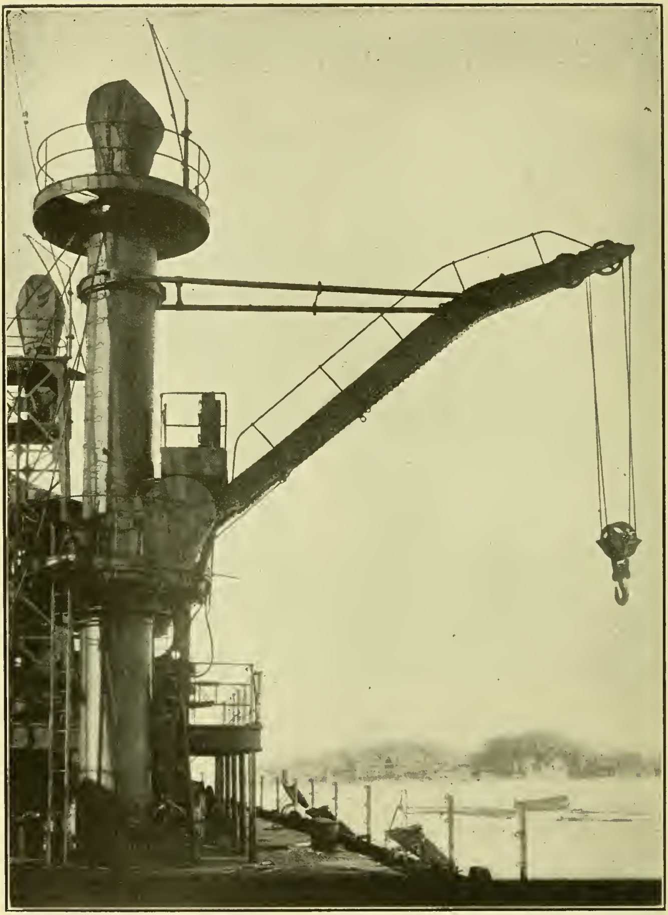

FIG. 12 CRANE FOR HOISTING BOATS ABOARD

This crane is operated by electric motors and has a capacity of 33,000 lb. Note the searchlight on top of the crane post and the one on the bridge. There are four 36-in. and four 60-in. searchlights on the ship.

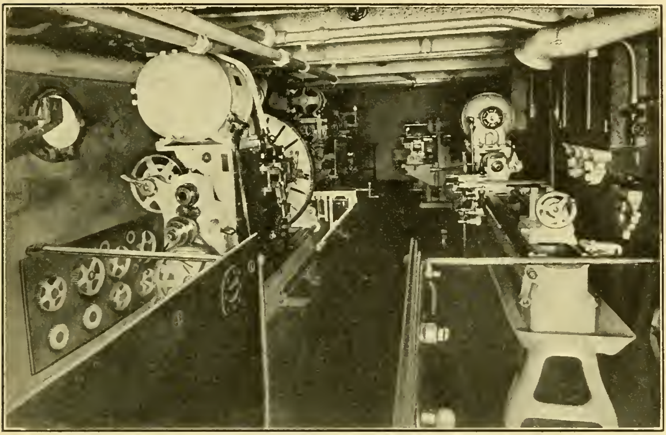

FIG. 13 WORKSHOP

Each tool is provided with individual motor drive and extensive repairs can be made on board the vessel.

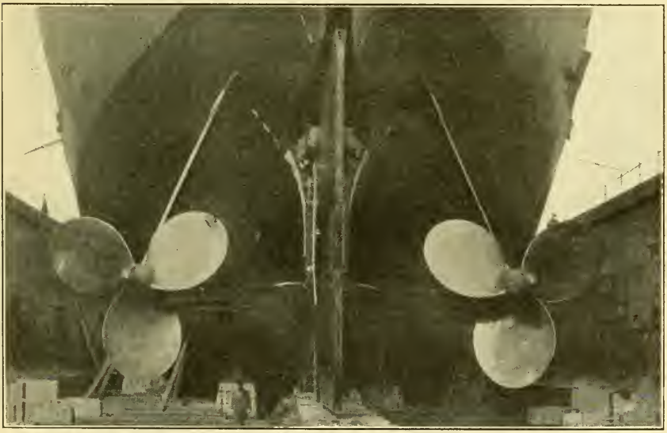

FIG. 14 STERN VIEW SHOWING PROPELLERS

The propellers are made of a new alloy known as Monel metal, containing about 60 per cent of nickel. The working surfaces are accurately planed to a true screw for a pitch of 10 ft. 4 in. and a diameter of 13 ft.

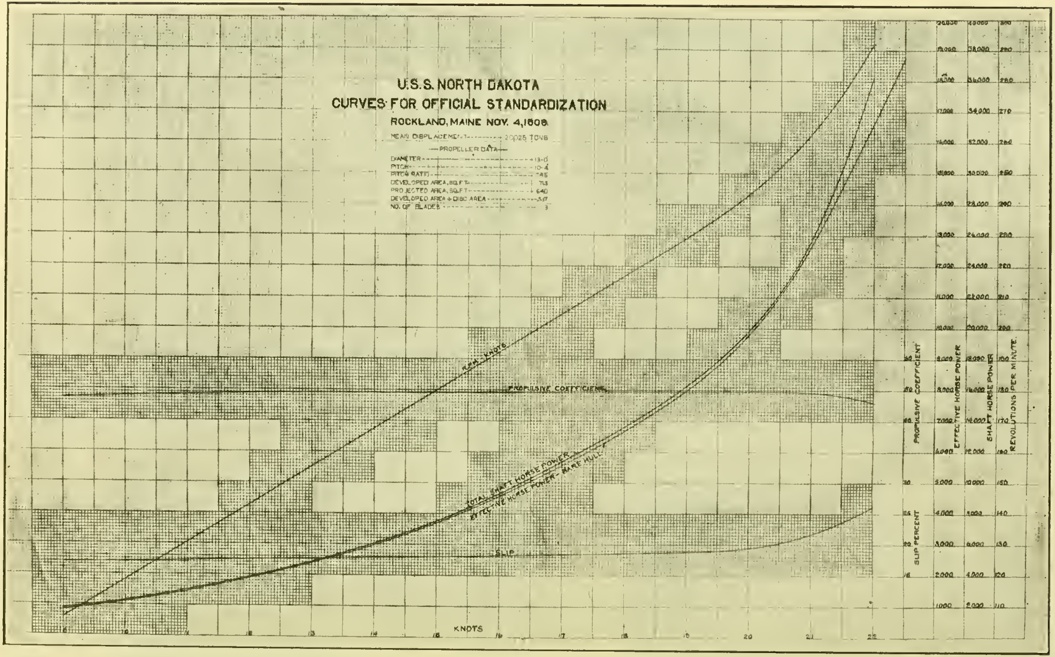

FIG. 15 HORSE POWER, SPEED AND REVOLUTION CURVES OBTAINED ON THE OFFICIAL TRIAL TRIP OF THE VESSEL

Note the rapid rise in power required as the speed increases.

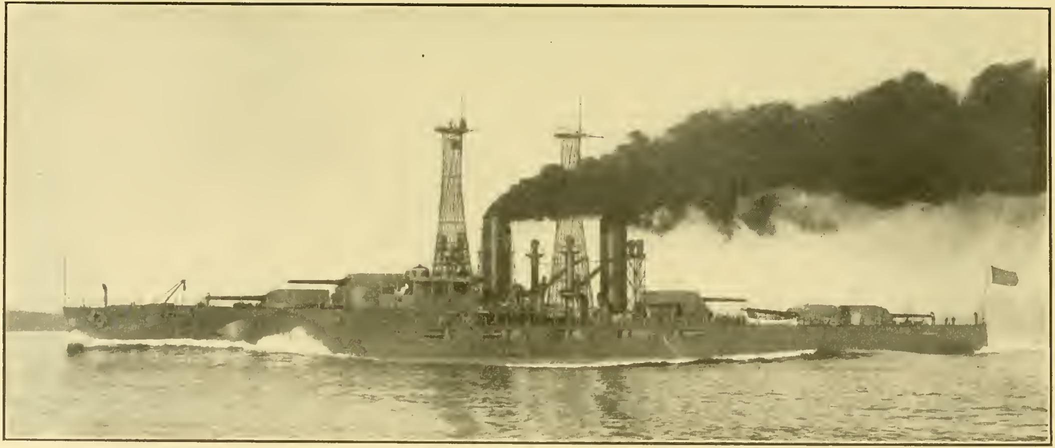

Fig. 16 The North Dakota Steaming at 22 Knots

This view, taken during the trial trip, shows the formation of bow and stern waves.

A number of additional views were shown and described, which are not reproduced, among which were some of the auxiliary machinery and a number of novel details of construction. These features include a refrigerating plant for cold storage purposes, ice-making, and cooling the magazine; the evaporating and distilling plant used to provide the vessel with fresh water, which has a capacity of 25,000 gallons in 24 hours, an engineering feature seldom found except on a battleship; a typical radiator, designed to heat the vessel in cold climates and to cool it in tropical regions, making comfort in any climate possible; the interior of the galley, with steam kettles and other means of cooking for the crew of 934 men, where a considerable amount of steam is used, constituting an engineering problem in itself.

A GRAPHICAL METHOD FOR CALCULATING STRESSES IN A CONNECTING ROD

By Winslow H. Herschel, New York

Member of the Society

Connecting rods are usually calculated by formulae. While empirical formulae are sufficiently accurate for slow engines where the inertia forces may be neglected, at how high a speed such formulae may be used is always a question. Thurston[1] gives two formulae, one for engines of moderate speed and the other for fast engines, but even in this case it is difficult to determine at what number of revolutions per minute we must discard one formula in favor of the other.

2 Analytical formulae are also unsatisfactory because they are based on incorrect assumptions. In the course of this paper I shall first enumerate the usual assumptions, and, taking up each in turn, show how it may be avoided, and finally give three numerical examples of the application of the new method.

3 *Assumption a.* The formula for calculating the bending moments due to the inertia forces may be written

$$M_1 = \frac{wR\omega^2(l^2x - x^3)}{6gl} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots [1]$$

where

M_1 = bending moment due to the normal components of the inertia forces in in. lb.

l = distance between the crosshead and crank pins, or length of rod, in in.

x = distance from the crosshead pin to the section under consideration, in in.

R = crank length, in in.

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[1] R. H. Thurston. A Manual of the Steam Engine, p. 103.

The American Society of Mechanical Engineers, 29 West 39th Street. New York. All papers are subject to revision.

g = acceleration of gravity, in in. per sec., squared

ω = angular velocity $= \frac{\pi n}{30}$, where n = r.p.m.

w = weight of an inch length of rod, in lb.

The definition of w indicates that the rod is of uniform section, although it is more common to use a tapered connecting rod for high speeds.

4 *Assumption b.* In deriving [1], Merriman[2] refers to a figure showing the crank at right angles with the connecting rod, that is, the piston has passed through about 44 per cent of the stroke. Unwin[3] shows the crank at right angles with the center line of the cylinder, that is, at 55 per cent stroke. Neither authority offers any proof of his assumption that the maximum bending moment occurs at the position indicated.

5 *Assumption c.* If $x = l\sqrt{\frac{1}{3}}$ in [1], M_i will have a maximum value of $0.0638\frac{wR\omega^2 l}{g}$. Hence it is assumed that the maximum bending moment due to the inertia forces is at a section distant from the crosshead pin 0.6 (more accurately 0.577) the length of the rod.

6 *Assumption d.* Since the inertia forces are usually regarded as the sole cause of bending, the maximum section of the rod is often placed at 0.6, the length of the rod from the crosshead pin.

7 Marks[4] corrects [1] for horizontal engines, by introducing the bending moments due to the static weight of the rod, and thus finds

$$M = \frac{wR\,\omega^2\,(l^2\,x - x^3)}{6\,gl} + \frac{wlx}{2}\left(1 - \frac{x}{l}\right)\ldots\ldots\ldots.[2]$$

The total bending moment, as given by [2], will have a maximum value when

$$x = l\left[-\frac{g}{R\omega^2} \pm \sqrt{\frac{1}{3} + \frac{g}{R\omega^2} + \left(\frac{g}{R\omega^2}\right)^2}\right]$$

This shows that the section of maximum bending moment will approach a point distant 0.577 the length of the rod from the crosshead end as the speed increases, and will approach the middle of the rod as the speed and consequently the inertia forces diminish.

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[2] Mansfield Merriman. Mechanics of Materials, p. 257.

[3] W. C. Unwin. Elements of Machine Design, vol. 2, p. 105.

[4] W. D. Marks. The Relative Proportions of the Steam Engine, p. 160.

[5] L. L. Willard. Corliss Engine Design. The Engineer, Dec. 1, 1906, p. 774.

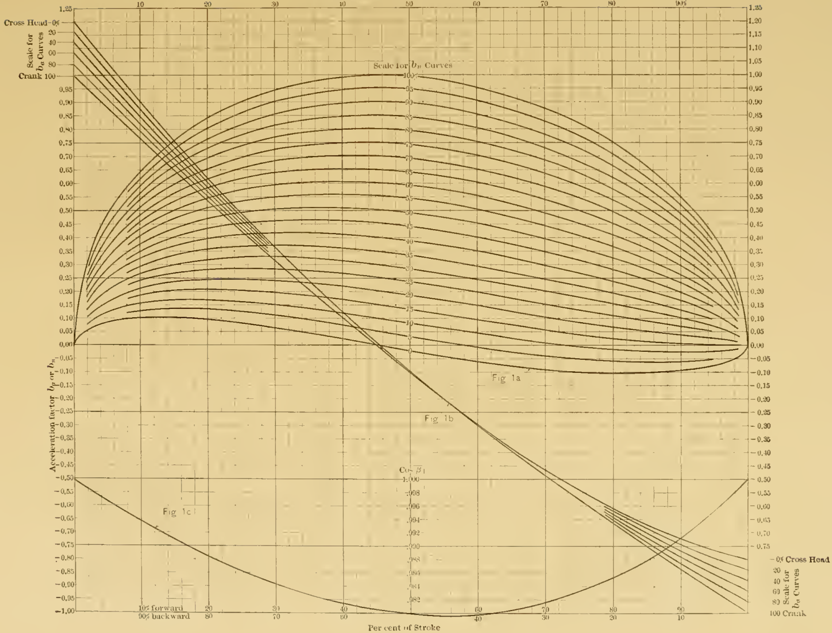

Fig. 1 Diagram to Determine Inertia Forces in Connecting Rod. Cylinder not offset $l/r = 5$.

8 L. L. Willard[5] uses a graphical method, which enables him to take account of the taper of the rod so far as it influences the bending moment due to the static weight. He assumes a rod of uniform section, however, in calculating the bending moment due to the inertia forces and the stress due to buckling and compression.

9 *Assumption e.* The axial thrust on the rod is taken as the piston area, multiplied by the unit pressure upon it and divided by cos β, where β is the angle between the connecting rod and the direction of stroke.

10 *Assumption f.* In addition to assuming, as in all structures, that the material is homogeneous, it is taken for granted in the case of a connecting rod that the workmanship is perfect, so that the rod may be considered as a column with no eccentricity of loading.

11 *Assumption g.* The maximum stress in the rod is taken as located at the section of maximum bending moment and as equal to the sum of the uniform stress due to the axial load, and the maximum stress due to the maximum bending moment. Expressed as a formula

$$\frac{P}{A} + \frac{M}{W} = K \quad \text{[3]}$$

where

P = axial load on rod, in lb.
A = section of rod, in sq. in.
M = bending moment, in in. lb.
$W = I/c$ = section modulus, in in. cubed
K = maximum stress in section, in lb. per sq. in.

12 If now we seek to avoid these seven assumptions, it soon becomes evident that we must use graphical methods. The analytical method would require a different formula for each shape of rod, and the calculations would be too complicated to be of practical value. I have therefore devised a graphical method, and shall show in the following paragraphs, that it obviates the necessity of making the seven assumptions.

DISCUSSION ON ASSUMPTIONS

13 In assumption *a*, since we wish to avoid the assumption that the rod is of uniform section, we must discard [1], in place of which we need some formula or other means of finding the normal component of the inertia force of a material point, which we will call P_n.

14 At the crank end of the rod the value of P_n will be

$$\frac{w}{g}\ R\omega^2 \sin(\alpha+\beta) = RwC \sin(\alpha+\beta)$$

where

w = weight of material point, in lb.
α = crank angle
β = rod angle
R = crank length, in in.
C = centrifugal force of 1 lb., 1 in. from center
(C can be obtained from a table or diagram.)

15 The inertia force at the crosshead end may be obtained from the formula

$$\text{inertia force} = \frac{bw}{g} = \frac{w}{g} R\omega^2 k = \text{approximately } \frac{wR}{g}\,\omega^2\,(\cos\alpha + \lambda\cos 2\alpha)$$

where

b = acceleration, in in. per sec., per sec.
λ = ratio of crank to rod length

16 In a paper entitled Influence of the Connecting Rod upon Engine Forces, Sanford A. Moss[6] gives the more accurate formula

$$k = \cos\alpha + \frac{\left(\frac{1}{\lambda}\right)\cos 2\,\alpha + \sin^4\alpha}{\left[\left(\frac{1}{\lambda}\right)^2 - \sin^2\alpha\right]^{\frac{3}{2}}}.$$

and calls attention to the typographical error in Unwin's Elements of Machine Design[7], of a minus instead of a plus sign in the numerator of the fraction.

17 In Hütte[8], is the formula

$$k = \frac{\cos(\alpha+\beta)}{\cos\beta} + \frac{\lambda\cos^2\alpha}{\cos^3\beta}$$

which agrees with the exact formula of Unwin. In all these formulae, however, careful attention must be paid to the geometrical signs of the sines and cosines. There is less chance of error in the graphical method shown by Autenrieth[9]. If we introduce in place of $\frac{\omega^2}{g}$, its equivalent C, we find that P_n at the crosshead end will be equal to $wCRk \sin \beta$.

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[6] Trans. Am. Soc. M. E., vol. 26, p. 375.

[7] W. C. Unwin. Elements of Machine Design, New edition, 1902, p. 117.

[8] Hütte des ingenieurs Taschenbuch, Akademischer Verein Hütte, Berlin, ed. 20, p. 829.

[9] Ed. Autenrieth. Beitrag zur Bestimmung der Trägheitskräfte einer Schubstange, in Zeitschrift des Vereins deutscher Ingenieure, vol. 39, 1895, p. 716.

18 We now have equations for the normal components of the inertia forces at both ends of the rod and may find intermediate values by simple interpolation If b_n is an inertia factor varying between $k \sin \beta$, and $\sin (\alpha + \beta)$, then P_n for any point in the rod may be determined by the formula

$$P_n = wCRb_n \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

19 Fig. 1a gives values of b_n for a normal crank mechanism where $\lambda = \frac{1}{5}$. The scale for b_n curves shows distance of material point from crosshead end in per cent length of rod. A plus sign on the out stroke or a minus sign on the back stroke before b_n shows that the force is acting upward in the case of a horizontal engine running over.

20 In cases where λ is not equal to $\frac{1}{5}$, a new diagram must be constructed in place of Fig. 1. $\lambda \sin \alpha = \sin \beta$, from which equation β may be calculated, and the percentage of stroke for any crank angle is

equal to $50\left[1 + \frac{1}{\lambda} - (\cos \alpha + \frac{1}{\lambda} \cos \beta)\right]$.

21 If the cylinder is offset, k may be found graphically, or the analytical method may be used as described by Professor Phetteplace in his paper, Offsetting Cylinders in Single-Acting Engines[10].

22 By means of Fig. 1a or a similar figure for the given conditions, and [4] we may find the value of P_n for each of the material points of which it is assumed the rod is composed. And since these forces produce neither a uniform nor a concentrated loading, we may most conveniently use the graphical or string polygon method for finding the bending moments M_i.

23 In assumption b, if we use Fig. 1a and [4] instead of [1] to determine M_i, it is evident that we are no longer restricted to the consideration of any particular part of the stroke, and we may find by trial at which point of the stroke M_i attains its maximum value. Fig. 1a shows that b_n for the middle point of the rod, or the average value of b_n for all points of the rod, reaches a maximum at about 38 per cent stroke, and this may be taken as the approximate position for maximum bending moment.

24 In assumption c, the graphical method of finding M_i locates the position as well as the value of the maximum bending moment due to the inertia forces. The error in assuming that the section of

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[10] Trans., Am. Soc. M. E., vol. 31, p. 223.

maximum bending moment is located 0.6 the length of the rod from the crosshead end is not material, but it leads to the more serious error of placing the maximum section of the rod at this point.

25 In assumption *d*, in addition to the bending moments due to P_n, bending is caused by the static weight of the rod, as pointed out by Marks[4] and Willard[5], both of whom, however, use [1] to calculate M_i and assume a horizontal rod in calculating the bending moments due to the static weight, which we will call M_w. By using the string polygon method, with the rod and forces drawn in their true directions, and by allowing for the taper of the rod in calculating the weights of the material points, values of M_w may be found accurately and without difficulty. On this account and because with a vertical engine M_w becomes negligible, it will not need further consideration. If taken account of in the case of a horizontal engine, it should be added to M_i.

26 The main error in the usual method of calculation is in neglecting the bending moment due to the axial load. The total bending moment, M, is equal to $M_i + M_f$, where M_i is the bending moment due to the normal components of the inertia forces, and M_f is equal to $P\ (e + f)$, P being the axial load on the rod, e the eccentricity of loading, and f the deflection of the rod.

27 For the determination of f it is most convenient to use Mohr's graphical method, described in a paper by Willibald Trinks on The Deflection of Beams by Graphics.[11] This method of finding deflections consists, briefly stated, in using a mean corrected bending moment in place of a force in the string polygon method of finding a bending moment. The bending moments are corrected by multiplying by the ratio $\frac{I_o}{I}$, I_o being a constant moment of inertia, usually that of the largest section of the beam, and I being the moment of inertia of each section where the deflection is to be found.

28 The length from center to center of supports is divided into a number of equal parts and the mean corrected bending moment found for each part. These mean values are then laid off on a force scale and treated just as if they were forces acting through the centers of the parts into which the beam was divided. The work of drawing a string polygon is then completed, just as when finding bending moments by that method, the only difference being in the determination and significance of the pole distance.

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[11] Trans., Am. Soc. M. E., vol. 24, p. 116.

29 Here we may use the formula

$$H = \frac{E I_o q}{lSxm} \dots\dots\dots\dots\dots [5]$$

where

H = pole distance
E = modulus of elasticity, in lb. per sq. in.
I_o = unit moment of inertia, in in. to the fourth power
q = number of equal parts into which beam is divided
l = length of beam between points of support, in in.
S = scale used in plotting corrected bending moments, being the number of in. lb. equal to 1 in.
m = number of times beam is reduced in size, in horizontal scale of string polygon, *e.g.*, if the scale is 3 in. = 1 ft., then $m = 4$
x = number of times deflection is to be enlarged on drawing.

q is selected according to the degree of accuracy required, and S is determined by the necessity of having the force scale a reasonable length. Then it is most convenient to calculate the value of $\frac{E I_o q}{lSm}$, after which x may be selected so as to bring the value of H as desired, that is, about half the length of the force scale, taking care that x is of such a value that the deflection may be easily scaled.

30 In assumption *e*, the axial thrust on the rod, P, is the sum of three quantities. The first is the pressure on the piston divided by cos β, the second is the inertia force of the purely reciprocating parts, divided by cos β, and the third is the axial component of the inertia forces of the rod itself, which we will call P_a.

31 Values of P_a are obtained by a method similar to that shown for finding P_n in Par. 22. At the crank end of the rod

$$P_a = \frac{w}{g} R\omega^2 \cos(\alpha + \beta) = RwC \cos(\alpha + \beta)$$

At the crosshead end of the rod

$$P_a = RwCk \cos\beta$$

or for any point on the rod

$$P_a = RwCb_a \dots\dots\dots\dots\dots [6]$$

Values of b_a are given on Fig. 1b, the scale for the b_a curves showing distance of material point from crosshead end, in per cent of length of rod. A plus sign on the out stroke or a minus sign on the back stroke before b_a shows that the force is acting towards the crosshead. Fig. 2 shows the relative values and directions of the inertia forces at both ends of the connecting rod when at ¼ and ¾ stroke. Fig. 1 also contains a curve marked Fig. 1c giving values of cos β.

32 In assumption *f*, Moncrieff[12] in his paper on The Practical Column under Central or Eccentric Loads shows that an eccentricity of loading of only a few thousandths of an inch has a very marked influence on the bending moment. As a result of the investigation of numerous tests on columns, he concludes that these tests could be made to harmonize if an eccentricity of loading were assumed large enough to cover the lack of homogeneity of the material as well as defects in alignment. He recommends taking a value of 0.6 for the ratio $\frac{ce}{r^2}$ where *c* is the distance to the extreme fibre, *e* is the eccentricity and *r* is the radius of gyration. This would give, for circular sections, the formula

$$e = 0.075\,d \ldots\ldots\ldots\ldots\ldots\ldots \quad [7]$$

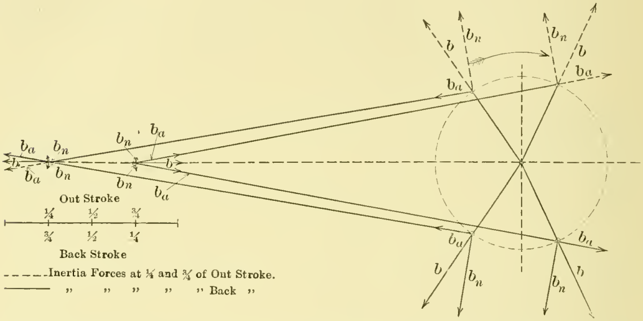

Fig. 2 Relative Values and Directions of Inertia Forces at Both Ends of the Connecting Rod when at ¼ and ¾ Stroke

Moncrieff does not consider tapered columns, but since [7] is at best only approximate, we may take *d* equal to the mean diameter of the rod.

33 In assumption *g*, in order to locate the section of maximum stress it is necessary to apply [3] to all sections of the rod. It would

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[12] J. M. Moncrieff, Trans. Am. Soc. C. E., vol. 45, 1901, p. 334-445.

be possible first to find the deflections due to the bending moments M_1, add e, and take M_f equal to the product of their sum by P. From the total bending moments, $M = M_1 + M_f$, new deflections could be found, and this operation could be repeated until the deflections were those due to M, and no further increase in deflection could be obtained.

34 The same result may be obtained more quickly by using the formula for increase in deflection of a column due to the load P when the column has an initial maximum deflection, v, due to normal forces. The formula is

$$\Delta = \frac{Pl^2\left(e + \frac{5}{6}v\right)}{8\,EI - \frac{5}{6}Pl^2} \dots\dots\dots\dots\dots\dots [8]$$

where

Δ = increase in deflection due to load P
e = eccentricity of loading
v = maximum deflection due to side forces

This formula is derived by Moncrieff in his paper [2] and will give approximate results in our case if I is the moment of inertia of the section with mean diameter.

35 If v has been found by Mohr's method[11] and Δ and e have been calculated by [7] and [8], we may find the maximum value of M_f from the formula

$$M_f = P\,(e + f) = P\,(e + v + \Delta) \dots\dots\dots\dots [9]$$

and the maximum bending moment to be resisted will be $M = M_1 + M_f$.

36 In cases where the rod is not of circular section it should be remembered that the bending moment in one direction is $M_1 + M_f$ and in the other direction simply M_f. In any case we may multiply the maximum bending moment by the ratio $\frac{I_0}{I}$ and assume the corrected bending moment thus obtained to be constant for the whole length of the rod, for if the maximum stress is constant, the corrected bending moment must be nearly so. Starting with this constant corrected bending moment we may proceed as before to find the true deflection by repetitions of Mohr's method.

37 For designing a rod of uniform stress with a circular section [3] may be brought into a more convenient form

$$\frac{P}{\frac{\pi d^2}{4}} + \frac{M}{\frac{\pi d^3}{32}} = K$$

$$M + \frac{Pd}{8} = \frac{K\pi d^3}{32}$$

or finally

$$d = \sqrt[3]{\frac{M + 0.125\ dP}{0.0982k}} \quad \ldots\ldots\ldots\ldots\ldots [10]$$

Equation [10] may be solved simply by assuming the value of d inside the cube root sign and recomputing when necessary.

PROPOSED METHOD OF DETERMINING STRESSES

38 We now have all the formulae needed to determine the stresses in an existing rod or to design a new rod with constant stress without need of the seven assumptions above stated, and I will next summarize the method to be employed in each case.

39 If we omit the ends of the rod, taking only the shaft, and divide it into equal parts of not too great length, we may assume without appreciable error that the center of gravity of each part is at the center of the part. This is of great convenience because it makes the lines of force coincide with the lines at the center of each of the strips used in finding deflections graphically. If the lines of force are taken through the actual centers of gravity of the material parts, it should be especially observed that the strips used in finding deflections must be equal, since otherwise [5] does not apply.

40 After finding the weight of each part of the rod, we must find values of P_n from [4] with the help of Fig. 1a. We find graphically the bending moments caused by the forces P_n and from these values of M_1 we find the deflections of the rod by Mohr's method[11], using [5] to find the pole distance. The maximum deflection thus found will be the value of v to be used in [8] together with the value of e from [7]. Equation 9 now gives the first trial value of the maximum bending moment due to buckling, and adding the maximum value of M_1 already obtained graphically and multiplying by $\frac{I_0}{I}$ for the middle of the rod, we have a trial value of the corrected bending moment, which is to be taken as constant for the whole length of the rod. Using this constant bending moment, we obtain new deflections by Mohr's method, but

these deflections are now values of f in [9] instead of their maximum being the value of v in [8]. We now proceed as before to find M_f, M and $\frac{MI_o}{I}$ and repeat the operations until no further increase in f may be obtained. The final values of M are then used in [3] to find K, the maximum stress at each section.

41 If we wish to design a rod that shall have a uniform stress, we may either start with a constant corrected bending moment or assume at first that the deflections are the same as found for an assumed rod. M is then found as before, but instead of multiplying by $\frac{I_o}{I}$ we must add $\frac{Pd}{8}$, divide by 0.0982 K and extract the cube root in order to find new values of d by [10]. From these new values of d we get $\frac{I_o}{I}$ and then $\frac{MI_o}{I}$ and are ready to repeat Mohr's method to get new values of f and thus of M. When final values of M have been obtained by successive repetitions of the process, the value of K as obtained from [3] should be constant and equal to the value of K assumed in [10].

NUMERICAL EXAMPLES OF APPLICATION OF THE METHOD

42 The proposed method may become clearer from the three following numerical examples. We will assume a vertical gas engine with a 16 in. piston, 12 in. crank, 5 ft. rod, and a maximum explosion pressure of 400 lb. per sq. in. which may occur at any point of the stroke. As will appear later, the axial thrust in rod due to inertia forces is small, so that P is practically equal to the maximum pressure on piston, or say $P = 80{,}000$ lb.

43 Problem 1 is to find the stresses in an assumed rod of uniform taper, $3\frac{3}{8}$ in. in diameter at the crosshead end, and $3\frac{5}{8}$ in. in diameter at the crank end, neglecting the weight of the rod ends. The numerical work is shown in Table 1.

44 Fig. 3 shows the graphical work of all three problems, with the various operations numbered. At the right may be seen the force scales, with only one horizontal ray drawn to locate the pole. At the top, in the form of inverted arches, are shown a few corrected bending moment diagrams. These are not absolutely necessary, unless the lines of force do not coincide with the center lines of the

TABLE 1 NUMERICAL WORK FOR PROBLEM NO. 1

1 Distance of Section from Crosshead, in per cent Length of Rod.	2 Weight of Material Point in lb.	3 b_n for 38 per cent Stroke from Fig. 1a	4 $P_n = 17.26 \times$ Col. 2 $\times$ Col. 3	5 M_1 from Operation No. 1	6 Diameter of Rod = d	7 $I = \frac{\pi d^4}{64}$	8 $\frac{I_o}{I}$	9 $\frac{M_1 I_o}{I}$	10 Deflection from Operation No. 2	11 Deflection from Operation No. 3	12 $f + e$ = Col. 11 + 0.262	13 M_f = Col. 12 × 80,000	14 M = Col. 13 + Col. 5	15 $\frac{MI_o}{I}$ = Col. 14 × Col. 8
0		0.033			3.37	6.33	1.320				0.262	210	210	277
5	15.2	0.081	21.2	1500	3.39	6.48	1.288	1930	0.0030	0.019	0.281	225	240	309
15	15.5	0.176	47.2	4400	3.41	6.64	1.258	5530	0.0088	0.050	0.312	250	294	369
25	15.7	0.272	73.7	7080	3.44	6.87	1.215	8600	0.0137	0.069	0.331	265	336	408
35	15.9	0.368	101.2	9280	3.46	7.03	1.188	11030	0.0173	0.081	0.343	274	367	436
45	16.2	0.464	129.	10890	3.49	7.28	1.147	12480	0.0194	0.088	0.350	280	389	446
55	16.4	0.559	159	11740	3.51	7.45	1.120	13160	0.0198	0.088	0.350	280	397	444
65	16.6	0.655	188.	11580	3.54	7.71	1.082	12500	0.0181	0.081	0.343	274	390	422
75	16.9	0.751	218.	10320	3.56	7.88	1.059	10920	0.0147	0.069	0.331	265	368	390
85	17.1	0.846	249.	7710	3.59	8.15	1.025	7880	0.0096	0.050	0.312	250	327	335
95	17.3	0.942	281.	3310	3.61	8.34	1.000	3310	0.0034	0.019	0.281	225	258	258
100		0.990			3.62	8.43	0.990				0.262	210	210	208

1 Distance of Section from Crosshead, in per cent Length of Rod	16 Deflection from Operation No. 4	17 $f + e$ = Col. 16 + 0.262	18 M_f = Col. 17 × 80,000	19 M = Col. 18 + Col. 5	20 $\frac{MI_o}{I}$ = Col. 19 × Col. 8	21 Deflection from Operation No. 5	22 $f + e$ = Col. 21 + 0.262	23 M_f = Col. 22 × 80,000	24 M = Col. 23 + Col. 5	25 $A = \frac{\pi d^2}{4}$	26 $\frac{P}{A} = \frac{80,000}{\text{Col. 25}}$	27 $W = \frac{\pi d^3}{32}$	28 $\frac{M}{W} = \frac{\text{Col. 24}}{\text{Col. 27}}$	29 K = Col. 26 + Col. 28
0									210	8.92	8990	3.76	5580	14570
5	0.014	0.276	221	236	304	0.014	0.276	221	236	9.02	8880	3.82	6180	15060
15	0.037	0.299	239	283	355	0.036	0.298	239	283	9.13	8770	3.89	7280	16050
25	0.056	0.318	254	325	394	0.055	0.317	254	325	9.29	8620	4.00	8130	16750
35	0.069	0.331	265	358	425	0.067	0.329	263	356	9.40	8520	4.07	8750	17270
45	0.075	0.337	270	379	434	0.073	0.335	268	377	9.57	8370	4.17	9030	17400
55	0.075	0.337	270	387	433	0.073	0.335	268	385	9.68	8270	4.24	9070	17340
65	0.068	0.330	264	380	411	0.066	0.328	262	378	9.84	8130	4.35	8700	16830
75	0.055	0.317	254	357	378	0.054	0.316	253	356	9.95	8040	4.43	8050	16090
85	0.037	0.299	239	316	324	0.036	0.298	239	316	10.12	7910	4.54	6970	14880
95	0.013	0.275	220	253	253	0.013	0.275	220	253	10.23	7820	4.62	5480	13300
100									210	10.29	7770	4.66	4510	12280

strips used in finding deflections, but it is convenient to plot them in order readily to see the changes of corrected bending moment with successive repetitions of Mohr's method. At the bottom of Fig. 3 is drawn the rod as assumed for problem 1, and as calculated in problem 2. The main part of the figure is covered with string polygons used in finding M_1, v, and f.

45 With $R = 12$ in. and a speed of 225 r.p.m., $C = 1.4386$, and by [4], $P_n = 17.26\, wb_n$, values of P_n being given in column 4 of Table 1.

46 Graphical operation No. 1 gives the bending moments due to inertia forces, by the simple string polygon method, using the loads given in column 4. From the assumed diameters of the rod we must next get the ratios $\frac{I_o}{I}$, in order to correct these bending moments by Mohr's method,[11] in graphical operation No. 2, from which we get the deflections of column 10. The maximum value, 0.0198 in., is equal to v, and we may now find by [8]

$$\Delta = \frac{80{,}000 \times (60)^2 \left[0.075 \times 3.5 + \left(\frac{5}{6} \times 0.0198\right)\right]}{(8 \times 30{,}000{,}000 \times 7.37) - \frac{5}{6} \times 80{,}000 \times (60)^2} = 0.0525 \text{ in.}$$

By [7]

$$e = 0.075 \times 3.5 = 0.2625 \text{ in.}$$

and thus by [9]

$$M_f = 80{,}000\ (0.2625 + 0.0198 + 0.0525) = 26{,}800 \text{ in. lb.}$$

and adding the maximum value of M_1 from column 5 we get M = 38,540. But for the mean diameter of 3.5 in.

$$\frac{I_o}{I} = \frac{8.34}{7.37} = 1.133$$

so that our corrected bending moment is equal to

$$38{,}540 \times 1.133 = 43{,}700$$

47 This value is assumed constant, that is, the corrected bending moment diagram would be a straight line if shown in Fig. 3. Thus the distances laid off on the force scale, in operation No. 3, are equals and give deflections as shown in column 11. Adding the value of e, already found, we get $f + e$ of column 12, from which M_f, in column 13, is found by [9]. Column 13 and all subsequent bending moments in Table 1 are expressed in hundreds of in. lb.

48 Having now both M_i and M_f, their sum multiplied by the ratio $\frac{I_o}{I}$ gives the new corrected bending moments of column 15, and these are used in operation No. 4 to obtain new deflections. Repeating in columns 17 to 20 the same calculations as in columns 12 to 15 we again return to our graphical method in operation No. 5 to

TABLE 2 NUMERICAL WORK FOR PROBLEM NO. 2

1 Distance of Section from Cross-Head, in per cent Length of Rod	2 Deflection from Operation No. 6	3 $f + e =$ Col. 2 + 0.262	4 $M_f =$ Col. 3 × 400,000	5 $M =$ Col. 4 + Col. 5 of Table 1	6 $\frac{Pd}{8} = 50{,}000 \times$ Col. 6 of Table 1	7 Col. 5 + Col. 6	8 $d^3 = \frac{\text{Col. 7}}{3930}$	9 $d = \sqrt[3]{\text{Col. 8}}$	10 I	11 $\frac{I_0}{I}$	12 $\frac{MI_0}{I} =$ Col. 11 × Col. 5	13 Deflection from Operation No. 7	14 $f + e =$ Col. 13 + 0.378	15 $M_f =$ Col. 14 × 400,000	16 $M =$ Col 15 + Col. 5 of Table 1
0		0.262	105	105	169	274	69.6	4.11	14.0	3.03	318		0.378	151	151
5	0.167	0.429	172	173	170	343	87.2	4.43	18.9	2.25	389	0.031	0.409	164	165
15	0.425	0.687	275	279	171	450	114.6	4.85	27.2	1.565	437	0.081	0.459	184	191
25	0.630	0.892	357	364	172	536	136.3	5.14	34.3	1.239	451	0.120	0.498	199	208
35	0.764	1.026	410	419	173	592	150.7	5.32	39.3	1.080	453	0.146	0.524	210	221
45	0.830	1.092	437	448	174	622	158.0	5.41	42.0	1.010	453	0.159	0.537	215	227
55	0.830	1.092	437	449	175	624	158.9	5.42	42.4	1.000	449	0.159	0.537	215	227
65	0.764	1.026	410	422	177	599	152.5	5.34	39.9	1.064	449	0.145	0.523	209	219
75	0.630	0.892	357	367	178	545	138.8	5.18	35.3	1.202	442	0.120	0.500	200	208
85	0.425	0.687	275	283	179	462	117.6	4.90	28.3	1.500	424	0.081	0.459	184	192
95	0.167	0.429	172	175	180	355	90.2	4.48	19.8	2.15	376	0.031	0.409	164	167
100		0.262	105	105	181	286	72.7	4.18	15.0	2.84	298		0.378	151	151

1 Distance of Section from Cross-Head, in per cent Length of Rod	17 $\frac{Pd}{8} = 50{,}000 \times$ Col. 9	18 Col. 16 + Col. 17	19 $d^3 = \frac{\text{Col. 18}}{3930}$	20 $d = \sqrt[3]{\text{Col. 19}}$	21 I	22 $\frac{I_0}{I}$	23 $\frac{MI_0}{I} =$ Col. 16 × Col. 22	24 Deflection from Operation No. 8	25 $f + e =$ Col. 24 + 0.365	26 $Mf =$ Col. 25 × 400,000	27 $M =$ Col. 26 + Col. 5 of Table 1	28 $\frac{Pd}{8} = 50{,}000 \times$ Col. 20	29 Col. 27 + Co .	30 $d^3 = \frac{\text{Col. 29}}{3930}$	31 $d = \sqrt[3]{\text{Col. 30}}$
0	205	356	90.3	4.48	19.8	1.586	239		0.365	146	146	224	370	94.0	4.55
5	222	387	98.3	4.61	22.2	1.415	233	0.022	0.387	155	156	230	386	98.2	4.61
15	243	434	110.7	4.80	26.1	1.203	230	0.057	0.422	169	173	240	413	102.5	4.68
25	257	465	118.3	4.91	28 5	1.102	229	0.083	0.448	179	186	245	431	109.5	4.78
35	266	487	124.0	4.99	30.4	1.032	228	0.101	0.466	186	195	250	445	113.2	4.83
45	270	497	126.6	5.02	31.2	1.008	229	0.110	0.475	190	201	251	452	115.0	4.86
55	271	498	126.8	5.03	31.4	1.000	227	0.110	0.475	190	202	251	453	115.2	4.86
65	267	486	123.7	4.98	30.2	1.040	228	0.100	0.465	186	198	249	447	113.7	4.85
75	259	467	119.0	4.92	28.8	1.090	227	0.083	0.448	179	189	246	435	110.8	4.80
85	245	437	111.2	4.81	26.3	1.195	229	0.057	0.422	169	177	240	417	106.0	4.73
95	224	391	99.3	4.63	22.6	1.390	232	0.022	0.387	155	158	231	389	99.0	4.63
100	209	360	91.5	4.50	20.1	1.563	236		0.365	146	146	225	371	94.3	4.55

TABLE 2—Continued

1	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47
Distance of Section from Cross-Head, in per cent Length of Rod	I	$\frac{I_o}{I}$	$\frac{MI_o}{I}$ = Col. 27 × Col. 33	Deflection from Operation No. 9	A	Weight of Material Point in lb.	b_n for 38 per cent Stroke, from Col. 3 of Table 1	b_n for 44 per cent Stroke, from Fig. 1a	$P_n = 17.26$ × Col. 37 × Col. 38	$P_n = 17.26$ × Col. 37 × Col. 39	M_1 from Operation No. 10	M_1 from Operation No. 11	$f + e$ = Col. 35 + 0.357	M_f = Col. 44 × 400,000	M = Col. 45 + Col. 42	$\frac{Pd}{8}$ = 50,000 × Col. 31
0	21 0	1.306	191		16.26								0.357	143	143	227
5	22.2	1.235	193	0.022	16.69	28.4	0.081	0.05	39	24	2900	2800	0.379	152	155	230
15	23.5	1.167	202	0.057	17.20	29.2	0.176	0.15	88	75	8200	8000	0.414	166	174	234
25	25.6	1.070	199	0.084	17.94	30.5	0.272	0.25	143	132	13200	12700	0.441	176	189	239
35	26.7	1.027	200	0.102	18.32	31.2	0.368	0.35	198	188	17200	16900	0.459	184	201	241
45	27.4	1.000	201	0.111	18.55	31.6	0.464	0.45	253	245	20100	19600	0.468	187	207	243
55	27.4	1.000	202	0.111	18.55	31.6	0.559	0.55	305	299	21400	21000	0.468	187	208	243
65	27.2	1.008	199	0.102	18.47	31.4	0 655	0.65	355	352	20900	20500	0.459	184	205	242
75	26.1	1.050	198	0.084	18.10	30.8	0.751	0.75	398	398	18200	17900	0.441	176	194	240
85	24.6	1.113	197	0.057	17.57	29.9	0.846	0.85	436	438	13100	12900	0.414	166	179	237
95	22.6	1.212	192	0.022	16.84	28.7	0.942	0.95	466	470	5300	5200	0.379	152	157	232
100	21.0	1.306	191		16.26			1.00					0.357	143	143	227

1	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62
Distance of Section from Cross-Head, in per cent Length of Rod	Col. 46 + Col. 47	$d^3 = \frac{\text{Col. 48}}{3930}$	$d = \sqrt[3]{\text{Col. 49}}$	I	$\frac{I_o}{I}$	$\frac{MI_o}{I}$ = Col. 46 × Col. 52	Deflection from Operation No. 12	$f + e$ = Col. 54 + 0.357	M_f = Col. 55 × 400,000	M = Col. 56 + Col. 42	A	$\frac{P}{A} = \frac{400,000}{\text{Col. 58}}$	W	$\frac{M}{W} = \frac{\text{Col. 57}}{\text{Col. 60}}$	K = Col. 59 + Col. 61
0	370	94.2	4.55	21.0	1.296	185		0.357	143	143	16.26	246	9.25	155	40100
5	385	97.8	4.61	22.2	1.225	190	0.022	0.379	152	155	16.69	240	9.62	161	40100
15	408	103.9	4.70	23.9	1.139	198	0.057	0.414	166	174	17.35	231	10.19	171	40200
25	428	109.0	4.78	25.6	1.062	201	0.085	0.442	177	190	17.94	223	10.72	177	40000
35	442	112.2	4.82	26.5	1.027	206	0.103	0.460	184	201	18 25	219	10.99	183	40200
45	450	114.5	4.85	27.2	1.000	207	0.112	0.469	188	208	18.47	217	11.20	186	40300
55	451	114.5	4.85	27.2	1.000	208	0.112	0.469	188	209	18.47	217	11.20	187	40400
65	447	113.8	4.84	26.9	1.012	207	0.103	0.460	184	205	18.40	217	11.13	184	40100
75	434	110.5	4.80	26.1	1.042	202	0.085	0.442	177	195	18.10	221	10.86	180	40100
85	416	105.7	4.73	24.6	1.106	198	0.057	0.414	166	179	17.57	228	10.39	172	40000
95	389	99.0	4.63	22.6	1.203	189	0.022	0.379	152	157	16.84	238	9.74	161	39900
100	370	94.0	4.55	21.6	1.296	185		0.357	143	143	16.26	246	9.25	155	40100

get deflections of column 21. Similarly columns 22 to 24 give corrected values of columns 17 to 19.

49 It is now seen that further repetition would not materially

change the result, and taking the values of M in column 24 as final, we may proceed to find K by [3]. It is seen that the greatest stress is at 45 per cent the length of the rod from the crosshead end, not at 60 per cent as usually assumed.

50 Problem No. 2 is to design a rod for the same engine as in problem No. 1, so that there shall be a uniform stress of 40,000 lb. per sq. in. under a load of 400,000 lb., that is, with P five times as great as previously assumed. For a starting point we may take M_i, v and e from problem No. 1. Then by [8]

$$\Delta = \frac{400{,}000 \times 3600 \times 0.279}{(30{,}000{,}000 \times 8 \times 7.37) - \left(\frac{5}{6} \times 400{,}000 \times 3600\right)} = 0.707 \text{ in.}$$

This high value of Δ would indicate that our assumed rod is too small, since, as a rough rule, a column may be considered as no longer serving its purpose when the deflection is greater than $\frac{l}{100}$ which, in our case, would be equal to 0.6 in. By [9]

$$M_f = 400{,}000 \ (0.2625 + 0.0198 + 0.707) = 396{,}000 \text{ in. lb.}$$

To this we add M_i, giving $M = 407{,}740$, and from this, multiplying by 1.133, the corrected bending moment is equal to 462,000.

51 In problem No. 1, graphical operation No. 2, we had by [5]

$$H = \frac{30{,}000{,}000 \times 8.34 \times 10}{60 \times 10{,}000 \times 200 \times 4} = 5.21 \text{ in.}$$

In operations Nos. 3 to 5 we kept this value for H by changing S from 10,000 to 40,000 and x from 200 to 50. Similarly, we may now in problem No. 2 change S to 400,000 in. lb. = 1 in. and change x to 5, and we shall still have $H = 5.21$ in.

52 By operation No. 6, using the constant corrected bending moment of 462,000 in. lb., we get the deflections as given in column 2 of Table 2. Taking the same value of e as in problem No. 1, we get $f + e$ in column 3, which multiplied by P gives values of M_f in column 4. Values M_f, M, $\frac{Pd}{8}$, $M + \frac{Pd}{8}$ and $\frac{MI_o}{I}$ in Table 2, are expressed in thousands of inch pounds. We then add values of M_i and get values of M in column 5.

53 Taking values for d inside the cube root sign, in [10], from column 6 of Table 1, we get new values of d as shown in column

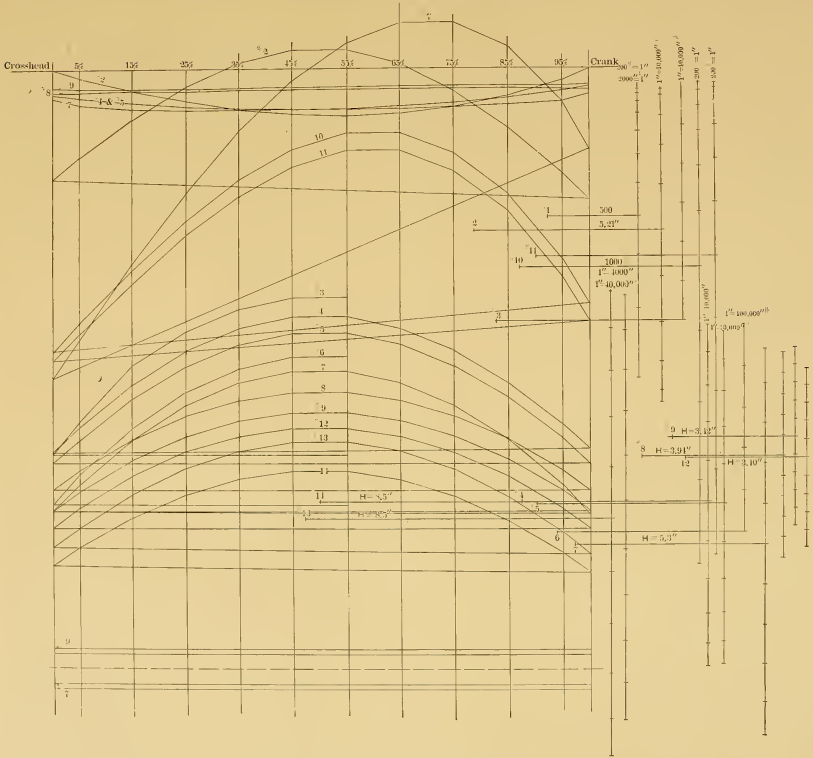

Fig. 3 Graphical Work of Problems 1, 2 and 3

9, and from these, new values of I, $\frac{I_o}{I}$ and $\frac{MI_o}{I}$. We are now ready to get, by operation No. 7, the new deflections shown in column 13. In operations Nos. 6, 7, 8, 9 and 12, values of H are proportional to I_o and are respectively 5.21, 5.30, 3.94, 3.42 and 3.40. In this respect problem No. 2 is unlike problem No. 1 where H is constant. It should also be noticed that e is variable, since the value of d in [7] changes with each repetition of Mohr's method.

54 Columns 14 to 23 carry out the same computation as column 3 to 12 and, after obtaining by operation No. 8 the deflections of column 24, we repeat in columns 25 to 34 the same computation. Operation No. 9 now shows deflections so nearly the same as those previously obtained that further repetition of the same line of calculations seems unnecessary.

55 We have thus far constantly used values of M_i from column 5 of Table 1, and must now eliminate this source of error by finding new values derived from the weight of a rod with diameters as given in column 31. Weights thus obtained are given in column 37.

56 We have assumed that the maximum bending moment due to inertia forces will be caused when the piston has traveled 38 per cent of the stroke, while according to the usual assumption the piston would have traveled about 44 per cent. Reading from Fig. 1 values of b_n for 44 per cent stroke and taking values for 38 per cent stroke as already found, we find values of P_n from [3] in columns 40 and 41. This gives us finally, by operations Nos. 10 and 11, values of M_i at 38 per cent stroke in column 42, and at 44 per cent stroke in column 43. It will be seen that while the differences are not large, values in column 42 are somewhat larger than those in column 43, and we may therefore continue to assume that the maximum bending moment occurs at 38 per cent stroke. The exact position for the maximum bending moment will evidently depend upon the distribution of weight in the rod.

57 We are now ready to run through our computation in columns 44 to 53, similar to columns 25 to 34, using the new values of M_i of column 42 to add to M_f in column 45.

58 Graphical operation No. 12 gives deflections of column 54 and these are so nearly the same as those in column 35 that we may take them as final. Adding e, multiplying by P and adding M_i, we get our final bending moments in column 57. From our final diameters in column 50 we get A and W, and then K may be found by [3].

The stresses in columns 59 and 61 are expressed in hundredths of pound per sq. in., and their sum, in column 62, should be 40,000. This does not, however, serve as a check on the graphical work.

59 For a comparison with the usual methods we may calculate the maximum diameter of a connecting rod, for the conditions of problem No. 2, by the formulae given in Kent.[13] Since $P = 80{,}000$ lb.

$$D\sqrt{p} = \sqrt{\frac{4\ P}{\pi}} = 319$$

Using these values and that of $l = 5$ ft. we may obtain the following table

No. of formula...	3	5	6	7	9	10
Diam. of rod, in...	5.80	5.70	3.81	6.48 and 3.94	8.47	6.48 and 6.82

Since neither factors of safety nor maximum stresses are stated with these formulae it is difficult to make a choice between them.

60 In the German handbook Hütte[14] may be found the formula

$$P = \frac{\pi^2 EI}{S\,l^2}$$

where S is the factor of safety against buckling, for which a value of 25 is given, and E is the modulus of elasticity. Taking $S = 25$ and $E = 30{,}000{,}000$, the formula reduces in English units, for a rod of circular section, to

$$d^4 = \frac{Pl^2}{592{,}000}$$

where

d = maximum diameter of rod at center, in in.
P = axial thrust on rod, in lb.
l = length of rod, in in.

This gives for our case, $d = 4.70$ in. which happens to be the average of the diameter at the end and at the middle as found by the graphical method.

61 The maximum stress in this rod is however much less, as found by the usual analytical method than as found graphically. Using the formula given in paragraph 5, assumption c,

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[13] Wm. Kent. Mechanical Engineers Pocket Book, p. 800.

[14] Hütte des ingenieurs Taschenbuch, Akademischer Verien Hütte, Berlin, ed. 20, p. 838.

$$M_1 \text{ maximum} = 0.0638 \frac{wR\omega^2 l^2}{g}$$

we find the maximum bending moment to be 19,550 in. lb. Assuming that the rod has a diameter of 4.70 in. at the point of maximum bending moment, the maximum stress, according to [3] would be

$$\frac{400{,}000}{17.40} + \frac{19{,}550}{10.20} = 24{,}900 \text{ lb. per sq. in.}$$

62 That the stresses found by the graphical method, and given in column 62 of Table 2, are so much greater is mainly due to the introduction of an eccentricity of loading. If $e = 0$, then, assuming the deflections to remain as given in column 54

$$M_f = 400{,}000 \times 0.112 = 44{,}800 \text{ in. lb.}$$

Adding $M_1 = 21{,}400$ from column 42, we get $M = 66{,}200$ from which the maximum stress due to bending would be $\frac{66{,}200}{11.20} = 5920$ lb. per sq. in. which would be a great reduction from the value of 18,700 given in column 61. If we omit M_f entirely, M becomes equal to M_i and the maximum stress due to bending is equal to $\frac{21{,}400}{11.20} =$ 1910 lb. per sq. in. or practically the same as found analytically.

63 Problem No. 3 is to find the stresses in the rod calculated in problem No. 2, when $P = 80{,}000$ lb. The method is similar to that used in problem No. 1, but we may simplify it somewhat by starting with the deflections as found for problem No. 2, instead of calculating Δ from v as before. The numerical work is shown in Table 3, in which all bending moments are expressed in hundreds of inch pounds. The graphical work is shown in Fig. 3, operations Nos. 13 and 14.

64 Columns 17 and 18 of Table 3 are used in checking our assumption that $P = 80{,}000$ lb. We have assumed that the piston has made 38 per cent stroke, and that the pressure upon it is 80,424 lb. Then in column 17 we have values of b_a from Fig 1b and from [6], the axial component of the inertia forces is equal to

$$P_a = 17.26\, wb_a$$

Taking weights from column 37 of Table 2, we get values of P_a in column 18, and the sum of this column is 810.5 lb. The inertia force of the piston weighing 700 lb. will be

$$700 \times 17.26 \times 0.168 = 2030 \text{ lb.}$$

acting against the pressure on the piston. Then P will be equal to

$$\frac{80{,}424 - 2030}{0.982} - 810 = 79{,}100 \text{ lb.}$$

where we have assumed the value to be 80,000.

65 It should be noticed that, in the case of a column or connecting rod, the maximum stress is not directly proportional to the load P. Thus if we assume in problem No. 2 that the ultimate strength of the material is 80,000 lb. per sq. in., we can not say that the factor of safety is 10 although a stress of 40,000 lb. per sq. in. would be obtained with a load five times the actual maximum load. In problem No. 3 the maximum stress was found to be 8980, and hence the factor of safety would be

$$\frac{80{,}000}{8980} = 8.90$$

TABLE 3 NUMERICAL WORK FOR PROBLEM NO. 3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Distance of Section From Cross-Head, in per cent Length of Rod	M_f = Col. 44 of Table 2 × 80,000	M = Col. 2 + Col. 42 of Table 2	$\frac{MI_0}{I}$ = Col. 3 × Col. 52 of Table 2	Deflection From Operation No. 13	$f + e$ = Col. 5 + 0.357	M_f = Col. 6 × 80,000	M = Col. 7 + Col. 42 of Table 2	$\frac{MI_0}{I}$ = Col. 8 × Col. 52 of Table 2	Deflection From Operation No. 14	$f + e$ = Col. 10 + 0.357	M .11 × 80,000	M = Col. 12 + Col. 42 of Table 2	$\frac{P}{A}$ = 80,000 ÷ Col. 58 of Table 2	$\frac{M}{W}$ = Col. 13 ÷ Col. 60 of Table 2	K = Col. 14 + Col. 15	b_a for 38 per cent Stroke from Fig. 1b	P_a = 17.26 × Col. 17 × Col. 37 of Table 2
0	286	286	370		0.357	286	286	370		0.357	286	286	4920	3090	8010	0.168	
5	304	333	408	0.006	0.363	291	320	392	0.005	0.362	290	319	4790	3320	8110	0.166	81.3
15	332	414	472	0.015	0.372	298	380	433	0.013	0.370	296	378	4610	3710	8320	0.164	82.5
25	354	486	515	0.023	0.380	304	436	462	0.020	0.377	302	434	4460	4060	8520	0.161	84.7
35	368	540	554	0.028	0.385	308	480	492	0.025	0.382	306	478	4380	4340	8720	0.159	85.5
45	376	577	577	0.030	0.387	310	511	511	0.027	0.384	307	508	4330	4540	8870	0.156	85.0
55	376	590	590	0.031	0.388	311	525	525	0.027	0.384	307	521	4330	4640	8970	0.154	83.9
65	368	577	584	0.028	0.385	308	517	523	0.025	0.382	306	515	4350	4630	8980	0.151	81.8
75	354	536	558	0.023	0.380	304	486	505	0.022	0.379	303	485	4420	4470	8890	0.149	79.2
85	332	463	510	0.016	0.373	298	429	474	0.014	0.371	297	428	4560	4120	8680	0.146	75.3
95	304	357	429	0.006	0.363	291	344	413	0.005	0.362	290	343	4750	3520	8270	0.144	71.3
100	286	286	370		0.357	286	286	370		0.357	286	286	4930	3090	8010	0.143	

66 It has been assumed in the problems that the rod ends had no weight, or what is the same thing, that their inertia forces acted

directly on the pins and so brought no stress upon the shaft of the rod. That there may be considerable error in this assumption is pointed out by Bach[15] in his conclusion that the resultant of all the inertia forces of the rod, including the ends, may pass through the crank pin, or in the case of a rod with a very heavy crank end, may fall beyond the pin.

67 This assumption is, however, not a necessary part of the method here proposed, since all equations, with the exception of [7] and [10], apply to a rod of any section. If we wish we may calculate the necessary diameters of a rod of full length to include the ends, and then make the end sections of the same area and section modulus.

68 The method of calculation described in this paper furnishes a means of finding the stress or the factor of safety at any point of a connecting rod. The usual assumptions are avoided, the only assumption necessary being in regard to the proper value of e to allow for lack of homogeneity of material as well as actual eccentricity of loading. It is evident that the greater the eccentricity assumed, the smaller will be the factor of safety required.

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[15] C. Bach. Die Maschinen-Elemente, p. 774.

INTERCHANGEABLE INVOLUTE GEARING

By Wilfred Lewis, Philadelphia, Pa.

Member of the Society

This paper was prepared at the request of the Meetings Committee of The American Society of Mechanical Engineers as the contribution to the discussion upon the need of a standard or standards for gears to be considered at the Joint Meeting with the Institution of Mechanical Engineers in July 1910. By way of explanation, it may be said that its author is chairman of a committee on Standards for Involute Gears, appointed about a year ago by the president of The American Society of Mechanical Engineers to investigate the subject of interchangeable involute gearing, and to recommend, if found desirable, a standard or standards. This paper, however, is not to be considered as an expression of the opinions of the other members of the committee, except where so stated.

2 After more or less unsatisfactory experience with cycloidal gearing, I investigated about twenty-five years ago the subject of involute gearing with the object of determining upon a system, for the firm of Wm. Sellers & Company, with which I was then connected. The conditions imposed called for a system applicable to any number of teeth between a 12-tooth pinion and a rack, without change in the Sellers addendum which had always been made 0.3-pitch for the cycloidal teeth, hitherto used almost exclusively by them.

3 I found that the involute forms then in vogue were confined to obliquities of 14½ deg. and 15 deg. with an addendum equal to the modulus, or about 0.32-pitch. This long addendum with such small obliquities naturally gave rise to interference between racks and pinions of less than 30 teeth, and rather than modify the involute form I finally recommended the adoption of a pressure angle of 20 deg. At the same time, I was well aware of the fact that even this obliquity was not sufficient to prevent interference between a 12-

Presented at the Birmingham, England, Meeting (July 1910) of The American Society of Mechanical Engineers and The Institution of Mechanical Engineers.

toothed pinion and a rack, but for such pinions and the gears of 60 teeth or less, with which they commonly engaged, I believed the interference would not be noticeable in practice. I was strongly tempted to go further and fix upon an obliquity of 22½ deg., but 20 deg. then appeared such a radical departure from common usage that the advantages of the greater angle were dismissed as being possibly more theoretical than real.

4 The 20-deg. system with an addendum of 0.3-pitch has now been in use by Wm. Sellers & Company for twenty-five years and has given satisfaction in a general way, although the interference referred to has been more or less noticeable on 12-toothed pinions. I reviewed this matter ten years ago in a paper read before the Engineers' Club of Philadelphia, advocating an obliquity of 22½ deg. and suggesting as a much-needed reform in engineering practice the consideration of uniformity in interchangeable gearing. I then pointed to the action of the Franklin Institute more than thirty years earlier, which inaugurated a standard system of screw threads and expressed the hope that by the interchange of opinions an agreement among engineers might be reached leading to the gradual disappearance of needless diversity in the forms of gear teeth.

5 Nothing in this direction had been done however, when the subject of interchangeable involute gear-tooth systems was brought to the attention of The American Society of Mechanical Engineers in a paper by Ralph E. Flanders presented in December 1908. A number of systems in general use were analyzed and their merits discussed from various points of view and the desire expressed that the Council be petitioned to appoint a committee to investigate the subject of interchangeable involute gearing and, if found desirable, to recommend a standard or standards.

6 In answer to this petition the Council voted in January 1909, that the President appoint a committee of five members to formulate standards for involute gears and present the same to the Council. Without anticipating in any way the conclusions of this committee yet to be formulated, if indeed an agreement be possible, I believe it will be helpful to give publicity to the line of investigation upon which we have embarked and thus obtain the benefit of such criticism or encouragement as it may provoke.

7 At the first meeting of the committee in June 1909, it was decided to obtain an expression of opinion from the manufacturers of gears and gear cutters and later in October the following circular letter was sent out:

Dear Sir:

A committee of The American Society of Mechanical Engineers has been appointed to consider the subject of standards for interchangeable involute gears, and would like to have as much light upon the subject as can be given them by the manufacturers.

Without limiting in any way the type of gears to be used for any special service, it is believed to be desirable that some type should be known as standard so that any gears of that standard may run together and be perfectly interchangeable.

The committee is, therefore, interested to know the extent to which involute gears are modified in your practice to avoid interference, and it would be pleased to have your ideas as to what, in your opinion, should constitute standard interchangeable involute gears. Any suggestion you may be pleased to offer will be very much appreciated.

Yours truly,

Wilfred Lewis, *Chairman*
Hugo Bilgram
E. R. Fellows
C. R. Gabriel
Gaetano Lanza
Committee on Standards for Involute Gears

8 In response to the circular letter above referred to, about one hundred answers were received, expressing more or less interest in the subject and giving more or less conflicting preferences and conclusions.

9 One correspondent said he would hail with delight any system whereby complete interchangeability could be attained on gears running without noise up to 1000 ft. a minute, as among automobile manufacturers noiseless gearing was always the chief end in view.

10 It is undoubtedly true, as pointed out by other correspondents, that perfect cutters do not necessarily produce perfect gears and that close attention must be paid to the setting of the cutter, proper indexing, speed, feed, etc., and from the extent to which the present $14\frac{1}{2}$-deg. system is established, it has been argued that even if the pressure angle of $14\frac{1}{2}$-deg. were not the most desirable, it would be better for the sake of the established practice to let it alone. Quite a number share this opinion and argue against the recommendation of a standard which may simply add another system to those already in use.

11 It may be said in reply that the chief advantages of involute gearing over cycloidal gearing which it has pretty generally displaced are the comparative simplicity of the involute curve and a slight variation in center distances not permissible in any other system of gearing. Despite the difficulty of securing general recognition for

any system of interchangeable gearing, I believe the committee should investigate and report upon some ideal standard or standards.

12 Attention is called by a number of correspondents to the increasing number of gears cut by the hobbing process and the difficulty of making such gears interchangeable with certain cut gears, thus indicating the hobbing principle as the first principle to which all cutters should conform, the rack being the basis of all generated gears. It is admitted that hobbed gears can be used interchangeably with gears cut by certain other processes, but some doubt is expressed of the possibility of realizing an interchangeable system using pinions with a small number of teeth and teeth of reasonable length without resorting to some modification of the involute curve. The opinion is freely expressed that if such modification becomes necessary the method should be known and clearly defined, so that makers of gears can adopt it and, if necessary, make their own cutters.

13 As pointed out in Mr. Flanders' paper and as mentioned repeatedly by our correspondents, the most desirable quality in gearing and the one by which it is almost universally judged, is quietness and smoothness of running. Next to this come strength, durability and permanence of form, and upon the last, of course, depend continued quietness and smoothness of action. Friction and journal pressure are of less importance, but still worth considering, and before reaching any conclusions from theoretical considerations alone, we propose to determine if possible, in a practical way, the relative advantages of some of the systems in common use and, with these, other systems to which we are disposed to give favorable consideration.

14 It is understood that the Institution would be pleased to have the coöperation of the Society in the work they have in hand looking to a determination of the friction in the transmission of power by gearing. In this connection we have been reminded of a suggestion of Prof. J. Burkitt Webb of Stevens Institute of Technology made soon after the publication of the Sellers' experiments upon gears reported to our Society in 1885. In these experiments an attempt was made to measure the friction loss between the teeth of a pair of spur gears, but the apparatus used, made originally for testing the friction of worm gearing, was not delicate enough for the purpose and the errors introduced exceeded, in some cases, the net result.

15 Professor Webb then suggested the possibility of so dividing one of the pair of spur gears to be tested as to make the load on the

teeth self-contained. The apparatus which we have designed embodies this idea, thus making it possible to run gears under heavy loads at high speeds with a very small consumption of power. We have also provided in our apparatus for an adjustment of center distance and means to measure the thrust between centers while the gears are running. Of course, the thrust between centers can be estimated very closely for involute gears from the pressure angle on the teeth, but we anticipate results somewhat in excess of this on account of the excess in friction of approach over that of recess, and, if any but involute gears are tested, it will also be interesting to compute from experimental data the effective obliquities of other systems.

16 We propose to determine the friction loss under various speeds and pressures for wheels and pinions cut to the Brown and Sharpe 14½-deg. standard, the 20-deg. stub tooth and a 22½-deg. tooth with addendum of $\frac{7}{8}$ module or about 0.278 pitch. These gears will be tested at normal center distance, and also at distances about 1 per cent or 2 per cent of the pitch greater or less than this, and an effort will be made to record graphically the noise produced under these different conditions.

17 We believe that accuracy and permanence of form can thus be given their proper influence on the reduction of noise. It may take some time to determine the effect of wear, but from the method of loading the teeth and the small amount of power consumed some indication of the tendency of wear can be obtained. All gears tend to wear out of shape, and involute gears more so than cycloidal, but we recognize as a possibility that this tendency may be checked by the deformation itself and also that the loss in friction at different parts of a gear tooth is practically incalculable on account of the variations in friction for different velocities of sliding.

18 The experiments we propose should therefore give information unobtainable in any other way and throw a flood of light on the problem in hand.

19 As it is quite impossible for any of the committee, who are all busy men, to make the experiments here outlined, we have been fortunate enough to interest, through the intervention of Professor Lanza of the Massachusetts Institute of Technology, two of his undergraduates, Messrs. Green and Doble, in making these experiments the subject matter for a graduating thesis. Professor Lanza hoped to have the work completed in June so that the results might be communicated for discussion at our Joint Meeting in July but this has proved impossible, partly because of the magnitude of the under-

taking and partly of the delay in the completion of the testing machine.

20 The apparatus used in making these experiments is shown by the photographs, Fig. 1 and Fig. 2, and the line drawing, Fig. 3, which gives some of the principal dimensions and shows the knife edges on which the machine rests. The machine consists of a frame *A* designed to carry a pinion shaft in roller bearings at one end, and a frame *B* pivoted to it and designed to carry the gear wheels *W* engaging with a wide-faced pinion *P* on the pinion shaft. The frame *B* is held to the frame *A* at its outer end by an adjustable clamping bolt *C*, and provision is made to measure the thrust on centers by means of the spring *D* acting between the frame *A* and an adjustable abutment on the frame *B*. The gear wheels to be tested consist of a central gear with a wide face and two side gears with narrow faces. The central gear carries two heavy cross pins *G*, which pass through clearance holes in the side gears, and the side gears carry two heavy pins *H*, which pass through clearance holes in the central gear. Between the projecting

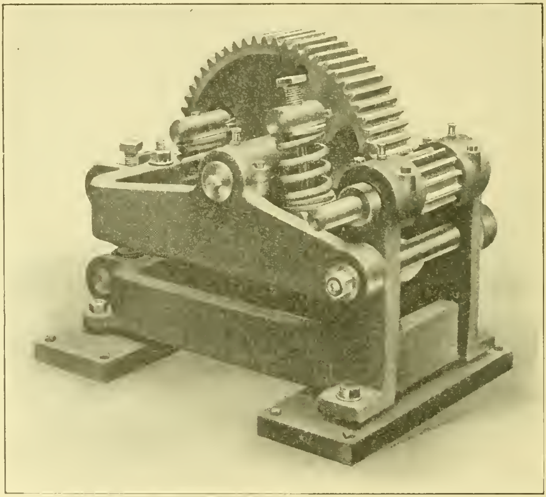

Fig. 1 Gear Testing Machine

ends of these pins G and H, heavy helical springs S are inserted, upon which pressure can be applied by means of the set screws K.

21 The pressure of these four springs S is resisted by the gear teeth, the middle gear pressing against one side of the pinion teeth and the side gears pressing against the other side. The pinion thus becomes simultaneously a driver and a driven gear and the power required to turn it when loaded in this way is only that required to overcome the friction of the teeth and whatever resistance there may be in the gear journals. The latter presumably is very small indeed, but provision has been made to measure it by substituting plain cylinders without teeth for the gears and pinion, and running these under the same journal pressures. By deducting the resistance due to journals from the total resistance with running gears, the friction of the teeth alone can be determined.

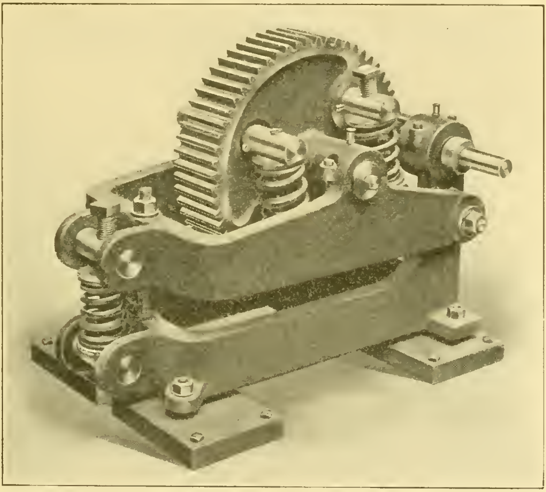

Fig. 2 View showing arrangement of Pivoted Frame and Spring for Measuring Thrust

22 In operation this machine is driven by an extension to the pinion shaft, carried to bearings several feet distant to permit of ample flexibility. The knife edge directly beneath the pinion rests

upon a permanent support, and the other knife edge is carried upon the platform of a small platform scales. The driving moment in the pinion shaft will therefore be measured by the scale reading at the end of an arm 20 in. long, and by reversing the direction of motion given to the pinion shaft the effect of any initial lateral strain in the driving shaft can be eliminated.

23 Fig. 4 illustrates three types of gearing to be tested by Messrs. Green and Doble, and with these other types may be included later on.

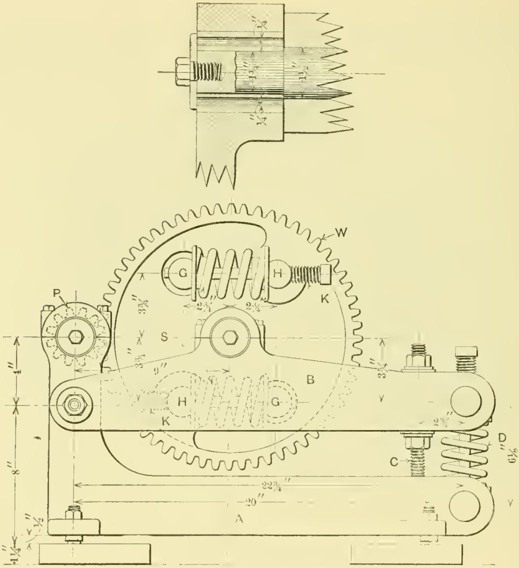

Fig. 3 Diagram of Gear Testing Machine

24 Figs. 5, 6 and 7 illustrate a group of involute gears designed by Mr. Bilgram to engage a rack of 15-deg. obliquity, and to demonstrate the possibility of using pinions of ten or even nine teeth with such a rack, provided the addendum can be varied. Without wishing to advocate the use of a variable addendum in interchangeable gearing, it is interesting to note the possibility of making a tentative solution of the problem in this way. A set of these gears has kindly been

furnished by Mr. Bilgram for making a comparative test. He has also made a set of models, from which the figures have been photographed, and referring to them, he gives the following explanation:

25 "While the involute system of gearing has decided advantages over any other, it has the one disadvantage that the faces of the teeth of wheels come into interference with the flanks of pinions, if the latter have a comparatively small number of teeth. Unless the flanks of the latter are undercut, the teeth will interlock or at least mesh improperly.

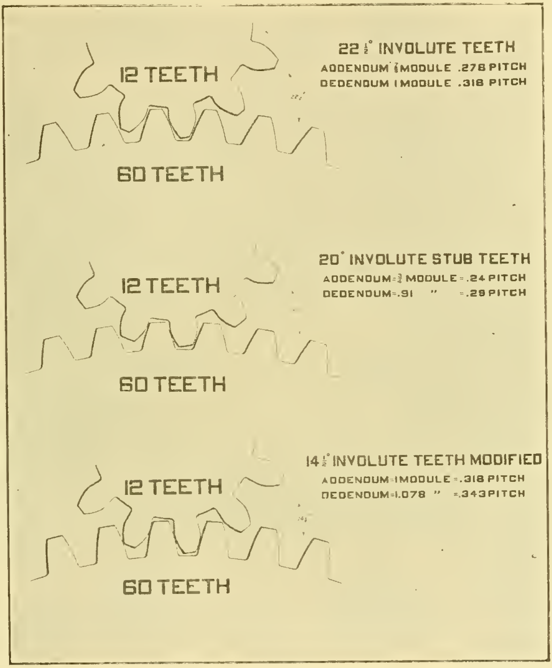
12 TEETH
60 TEETH
22½° INVOLUTE TEETH
ADDENDUM ⅞ MODULE .278 PITCH
DEDENDUM 1 MODULE .318 PITCH
12 TEETH
60 TEETH
20° INVOLUTE STUB TEETH
ADDENDUM = ¾ MODULE = .24 PITCH
DEDENDUM = .91 " = .28 PITCH
12 TEETH
60 TEETH
14½° INVOLUTE TEETH MODIFIED
ADDENDUM = 1 MODULE = .318 PITCH
DEDENDUM = 1.078 " = .343 PITCH

Fig 4 Gear Types Tested in the Machine

26 "In making a single pair of wheels, a remedy can readily be applied. There are two ways in which interference can be avoided,

namely either by increasing the angle of pressure or by shortening the addendum of the wheel. If the latter method is chosen and it is desired not to reduce the working depth of the teeth, it is necessary to add to the addendum of the pinion the amount taken from the addendum of the wheel.

27 "This latter method is out of the question when the problem is given to make an interchangeable set of spur wheels from a rack down to a 12-tooth pinion. This problem may be solved by a combination of both remedies alluded to."

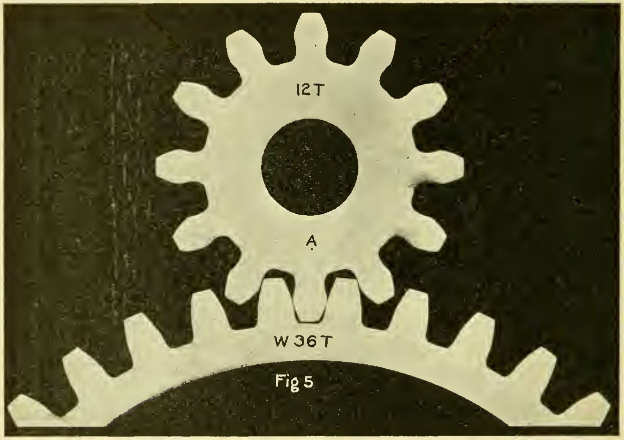

Fig. 5 Bilgram System: Pinion with Undercut Teeth

28 The method consists of making racks and larger wheels with normal addendum, but increasing the addendum of pinions just enough to prevent the rack tooth from interfering with the flank. The samples presented (Figs. 5 to 7) consist of a rack *R* and a 36-tooth wheel *W*, with angle of pressure of 15 deg. and addendum equal to the modulus. The 12-tooth pinion *A*, generated by a rack, corresponding to rack *R*, shows the undercutting thereby produced. Obviously this pinion will not work, as so much of the involute is cut away that the path of contact is materially less than one pitch. But there are also shown pinions of twelve, ten and nine teeth, made with increased addenda. These were generated by a rack like *R*,

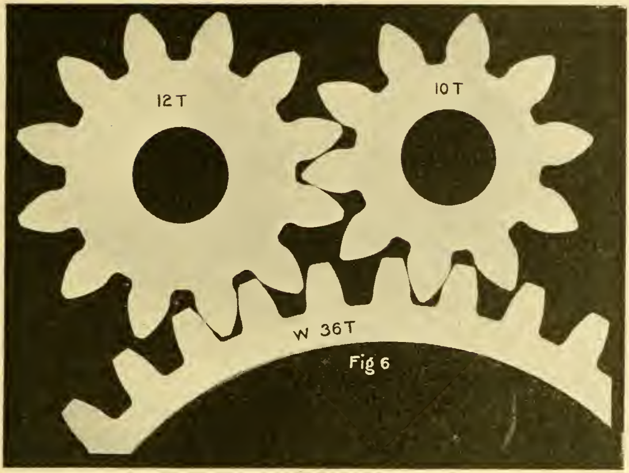

FIG. 6 BILGRAM SYSTEM: PINIONS WITH INCREASED ADDENDA IN MESH WITH GEAR

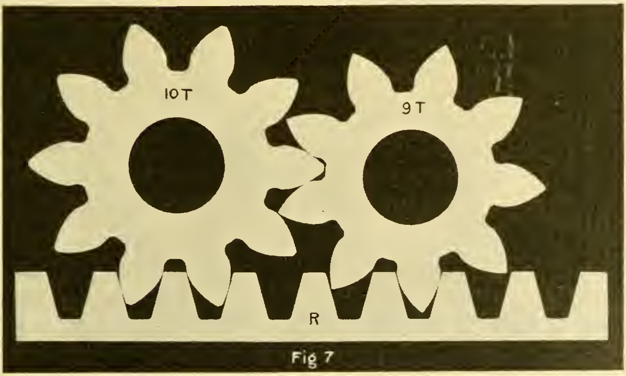

FIG. 7 BILGRAM SYSTEM: PINIONS WITH INCREASED ADDENDA IN MESH WITH RACK

but with a somewhat greater addendum than that used in generating the wheel W and a somewhat greater cutting depth. If these pinions are then mated with wheels of a large number of teeth, they will not enter as far as with pinions of equal number of teeth and have therefore a slightly less working depth.

29 On this plan may be based a system of involute gearing with a working depth of twice the modulus, and with a moderate pressure angle, 15 deg. in the samples submitted. Pinions of a small number of teeth will have an increased addendum, but a theoretically correct action is maintained. The pinion teeth have a wide base and are strong. One disadvantage in those cases in which pinions with less than about 24 teeth are embraced, is that the center distance is greater than that computed by the usual rule from the modulus and the number of teeth of the meshing wheels. Moreover, pinions will not have the full working depth when meshing with large wheels or with racks, but even in the case of a 10-tooth pinion meshing with a rack, the path of contact exceeds one pitch so that at least for a portion of the action two teeth will be in contact simultaneously.

30 The plan proposed by Mr. Fellows is to use an involute with an angle of pressure of 20 deg. and to reduce the addendum to $\frac{3}{4}$ of the modulus. Such teeth are known as "stub teeth". By this method interference in case of a rack gearing with a 12-tooth pinion is just avoided and in the case of two 12-tooth pinions meshing with each other the path of contact is equal to about $1\frac{1}{8}$ of the pitch.

31 Mr. Gabriel prefers the $14\frac{1}{2}$-deg. standard of the Brown and Sharpe Manufacturing Company and he has prepared a contribution to the discussion expressing his views on the subject.

32 The system which I propose is that of a pressure angle of $22\frac{1}{2}$ deg. and an addendum of $\frac{7}{8}$ of the modulus.

33 I believe that an interchangeable system of involute gearing, to be of the greatest value, should extend from a 12-tooth pinion to a rack, and in the selection of gears to be tested we have chosen a 12-tooth pinion engaging a 60-tooth wheel. The maximum reduction with the maximum strength in a limited space is the problem in gearing that generally confronts the engineer and a ratio of five to one is very often as much as he can realize without sacrificing too much strength. I recognize, of course, that the adoption of a larger number of teeth in the smallest allowable pinion overcomes some difficulties, and that this may be a debatable point, but I do not think any system of interchangeable gearing will be satisfactory which does not include pinions of twelve teeth. The cycloidal

system formerly employed was based upon a 12-tooth pinion, and I believe this number can be retained for the smallest number in an interchangeable involute system without serious objection. That is, there is better ground for the retention of this minimum number than for a higher number and when the pros and cons have all been summed up there will be no change in this well-established minimum for interchangeable pinions.

34 Although the experiments made under the direction of Professor Lanza are not by any means conclusive, enough has been done to indicate that the friction loss in gear teeth is influenced to a greater extent by the length of the addendum than by the obliquity of the system. Theoretically, the friction loss in involute teeth is independent of the obliquity and increases with the addendum. The loss in journal friction should vary as the secant of the pressure angle, but the latter is also affected by the dead weight on journals which even with plain bearings is a small matter, while with ball or roller bearings, it is a very trifling consideration indeed.

35 I believe therefore that a pressure angle of $22\frac{1}{2}$ deg. can be adopted without fear of reduced efficiency in the transmission of power; that an addendum of $\frac{7}{8}$ module will give an ample arc of action for all combinations of gears between a 12-toothed pinion and a rack, and that true involute forms made to these constants will avoid the necessity for any empirical modifications and give results comparable with the best now obtained by such means.

TOOTH GEARING

By J. D. Steven,[1] Assoc. Mem. I. M. E.

ABSTRACT OF PAPER

A paper upon Tooth-Gearing was also presented at the same meeting by J. D. Steven, copies of which have been sent to the members of the Society. In this paper different methods of cutting gears were discussed and different systems of tooth design were compared, with the conclusion that conditions have so radically changed during the past two years that there is every reason to consider the question with an open mind. If a new form of tooth is desirable, he believed that a stub tooth with 20-deg. pressure angle would be a change in the right direction, because it can be used in its true form down to 12 teeth; it is a stronger form and is most commonly used; and a large proportion of its face does useful work.

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[1] Messrs. E. G. Wrigley and Co., Soho, Birmingham, Eng.

DISCUSSION

Below is given the discussion presented at the meeting on the papers by Messrs. Lewis and Steven. This discussion will remain open until November 1 and additional contributions or comments are solicited from those interested.

P. V. Vernon[1] said he was present at the meeting as a patient and not as a doctor. He was connected with a firm of machine-tool makers, which had made many long and costly experiments with a view of determining, not what he might call academic points in the design of gearing, but for the purpose of obtaining a system of gears that would run silently at high speeds. His object in speaking was to ask that something might be done to discover the points that would give silence in gears, as until gears could be obtained which ran silently the question of making them interchangeable could hardly be profitably considered. The results of the experiments which his firm had made had been very small in the way of positive knowledge, but they had been very great negatively in the way of teaching them how very little anybody really knew about gearing. Among the negative results were the following: In the first place, it appeared that there was no general agreement among engineers or gear makers as to the best angle of pressure to use; there was no general agreement as to the proportions of gear teeth which were the best for quiet running; there was no reliable information on the strength of cut teeth made by modern methods in various materials and running at various speeds; there was no reliable information at present available on the effect of different materials on the strength, the noise, and the wear of gear teeth. It appeared, in fact, exceedingly doubtful whether it was possible to make an interchangeable system of gear teeth at all for quiet running.

2 Previous speakers had stated that the involute system was imperfect; engineers knew that the epicycloidal system was dead; and the results of the experiments which his own firm and others had made had proved that involute teeth did not give a quiet gear; that epicycloidal teeth did not give a quiet gear; that hobbed gears were not quiet, and that planed gears were not quiet. But there was one kind of gear which was quieter than all those, namely, the gear with "faked" teeth. It now was well known that the gears which gave the quietest results in running were those on which an empirical

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[1] Mem.I.M.E., Messrs. Alfred Herbert, Coventry, Eng.

correction of the tooth form had been made, and so far as he knew the means by which that correction was made were kept secret, and were in the hands of one leading American firm, of which a representative was present at that meeting. When Ralph E. Flanders read his paper before the American society in December 1908, this same representative of that firm practically admitted that the only way to get quiet gears was to make an empirical correction on an experimental basis, and that the best thing for gear users to do was to trust to the experience of that firm, which he (Mr. Vernon) supposed meant to buy their cutters from them. He spoke at that meeting as a member of both the Institution of Mechanical Engineers and of The American Society of Mechanical Engineers, and wished to say that although the greatest credit was due to that firm for having made their investigations and experiments, it was not to the interest of gear users in America and in England that that knowledge should continue to remain in their hands alone. He hoped the remarks he had made would do good by bringing the committee of The American Society of Mechanical Engineers, who were considering gear questions, into touch with the committee of the Institution of Mechanical Engineers, so that investigations might be started with a view to ascertaining what were the corrections which needed to be made to ensure quiet tooth action, and so that such information, when obtained, could be placed in the hands of gear users in both countries.

C. R. Gabriel. This discussion was prepared at the request of the Meetings Committee of The American Society of Mechanical Engineers as a contribution upon standards for gears, and is submitted as a personal opinion, rather than a report, as the findings of the committee up to date have not established definite conclusions.

2 As stated, the committee received in reply to its circular letter, a large number of answers, but few contained comparative data and were largely expressions of theories or opinions, such as most engineers have advanced in explanation of the difficulties arising from improperly cut and noisy gears. The expression "improperly cut" is used advisedly, as from an experience covering a long period of years the writer believes that nine-tenths of all the trouble with noisy gears can be attributed to improper cutting.

3 As regards the adoption of a standard, the opinion of the writer is that the present so-called Brown and Sharpe standard will hold its own against any system for the general run of machinery; and that for many of the cases where special cutters or forms of teeth are used,

the benefits of such modifications are more imaginary than real. The answer to the difficulties arising where high speed, durability and efficiency are required, will be found in the substitution of better material and better methods of treating in the hardening process.

4 The present system is called by some an empirical one, but any carefully-worked out system will be so, as practice shows that decidedly better results are obtained by certain modifications of the theoretical tooth form. Teeth having an increase of pressure-angle and reduction of addenda to prevent undercutting on 12-tooth pinions would be subject to the same modifications which would put them in the empirical class, and any manufacturer of cutters would undoubtedly strive to improve his cutters regardless of whether they were strictly in accordance with theory.

5 The opinion is expressed that if such modifications are necessary, the methods should be known and clearly defined, so that makers of gears can use them and make their own cutters, if necessary. The advantages to the gear manufacturer of making his own cutters are not apparent to the writer, as the difficulties attending the making of form cutters would prove expensive in comparison with the convenience of using commercial stock cutters produced by reliable cutter manufacturers.

6 Attention has been called to the increasing number of gears cut by the hobbing process, and the difficulty of making such gears interchange with certain cut gears, thus demonstrating that the hobbing principle is the one to which all cutters should conform. This seems misleading, as the fact is not mentioned that this process has its limitations. It must not be overlooked that one great disadvantage arises from the difficulty experienced in producing accurate hobs.

7 The method of producing gear teeth by the shaping process has also been actively exploited, and the committee's attention has been called to the fact that it is an incidental feature of this process that the regular standard 14½-deg. cutters (on account of the side strain involved) are less durable than the usual form of revolving cutter, especially under rapid production requirements, and in tough material. The proposed 20-deg. pressure angle stub tooth materially increases the strength of the reciprocating gear-shaper cutter. The writer also calls attention to the fact that the stub-tooth system would greatly reduce the difficulties in producing the hobs for the hobbing process referred to above, and believes the committee should be very conservative in its recommendations, particularly where they appear to favor some method or methods of producing gear teeth.

8 As regards the forms of teeth referred to in the paper as submitted by the other members of the committee, Mr. Fellows proposes to use an involute with 20-deg. pressure angle, and an addendum of $\frac{3}{4}$ of the modulus. Mr. Lewis proposes an involute with $22\frac{1}{2}$-deg. pressure angle, and an addendum of $\frac{7}{8}$ of the modulus. Both of these systems are subject to criticism for general adoption, (*a*) because of increased angular back-lash, as compared with the present $14\frac{1}{2}$-deg. standard for a like amount of wear; (*b*) decrease of addendum which is decidedly objectionable on the smaller pitches, as the liability of error in depth of tooth and center distance of shafts remains a constant for all pitches and sizes of gears, and the present height is none too great, being increased for these reasons for some purposes.

9 Further, it is claimed for the stub-tooth system that the arc of contact is equal to that of the $14\frac{1}{2}$-deg. Brown and Sharpe standard, and that consequently the excess of tooth height in the standard system produces unnecessary friction and wear, which is eliminated in the stub-tooth system. The fact is not mentioned that in the Brown and Sharpe system the height of tooth permits of being eased off towards the point, with the result that it causes no friction if the integrity of the tooth form is maintained, but as wear cannot be entirely eliminated this easing of the points of the teeth allows the engaging teeth to come into action without shock, thus reducing noise and the dynamic action which tends to destroy the gears by the contacting of the teeth and is similar to hammer blows. Also, in practice the standard length of tooth will conjugate itself with its mating gear, with the result that more than one set of teeth take the load. This may produce extra friction, as claimed, but with properly lubricated gears this is a negligible quantity, as the unit stresses are divided over more than one set of teeth. The stub tooth has greater strength, but, for the reason cited above, does not prove as satisfactory for all-round service.

10 In this connection, the writer wishes to refer to the situation in motor gears used in street-car service. From personal observation he has seen stub-tooth gears where this dynamic action seemed to have broken down the structure of the steel to such an extent that it came off in splinters where the points of the teeth seemed to have bitten the material away. The best results the writer has seen in this class of work are where gears and pinions have been cut to the Brown and Sharpe system and carbonized and case-hardened, with the result that after a year's use there was only glazing of the contact surfaces.

11 As to the matter of testing, the committee are united on its desirability, but the writer does not believe that anything definite or conclusive can be obtained from testing a few pairs of gears. The tests should cover a large number of gears of more than one pitch and of several different ratios of teeth. These tests should be so exhaustive as to leave no opportunity for engineers to feel that anything has been assumed. This means great expense and much time, and the writer would recommend that the coöperation of all interested parties be secured, that a fund be raised for the purpose of employing competent engineers to conduct exhaustive tests with suitable apparatus, and that all available materials be used, so that the differences of opinion as to the efficiency of the various systems in use may be set at rest as far as possible. Also this should establish reliable data for proportions of gears of the various materials, now mainly a matter of judgment with the designing engineer, from which more gear failures result than from any fault of the system of teeth used.

12 To sum up the situation, the writer believes that where the limits of an interchangeable system are from a 12-tooth pinion to a rack, the present system is superior to any which are primarily based on the generating principle, in which the pressure angle and tooth parts are proportioned to facilitate the methods of producing and strengthening the cutting tools, rather than to improve the interchangeability or more quiet running of the gears, as that is a fact still to be demonstrated. The circular letter sent out by the committee brought out the information from one concern that it had experimented exhaustively with the hobbing system for a long time, with various tooth forms, but had gone back to the Brown and Sharpe standard, for which they had now worked out a most satisfactory method of making the hobs. This is another example of the working out of an empirical system, and any satisfactory system covering the range stipulated, which, as before stated, must be an empirical one, had best be left to responsible cutter manufacturers whose methods combine the theoretical with the practical. The present Brown and Sharpe system has proved itself eminently satisfactory for many years, and without most thorough investigation should not be given a place second to any other. Also the introduction of an alternative standard or standards is to be deprecated on the ground of causing confusion and economic waste, due to the increased stock of cutters required for use on all types of machines.

13 In conclusion, the writer wishes to refer to the point raised in some of the replies to the committee's letter, that the question of

standardizing gearing is of the same nature as screw-thread standardization, and can be treated in the same way. Without referring to the conclusions reached by the Committee on Screw Threads, the deliberations of which consumed several years, the writer fails to see wherein the problems set forth by the two subjects can be compared. The screw-thread situation was one to be settled by common consent of all concerned, while the problem of gearing is one that is worthy the life work of any engineer, and involves much of the higher mathematics of engineering, as well as a thorough knowledge of applied kinematics. The fact that such a comparison has been made by some writers on the subject, only serves to show an utter lack of appreciation of the magnitude of the problem set before the committee for its consideration and recommendation to the Society.

Luther D. Burlingame said he appreciated all Mr. Vernon had said with regard to their policy at the Brown and Sharpe works, but he thought the point which had been raised was very well answered by the communication of Mr. Gabriel to which the members had just listened. Speaking for a manufacturer, at whose works for more than sixty years an extensive business in making gears and gear-cutters had been done, and which had had to deal with all phases of the gear question and meet the varying requirements of customers during those years, he could say they were not surprised that the different members of the committee of The American Society of Mechanical Engineers were not unanimous as to any plan which would bring about a change from the present standard. The thought seemed to be uppermost in the minds of those proposing a change that a standard should be adopted having a true involute for the entire length of the tooth, even if sacrifices in other directions must be made to accomplish that result. He believed the advantage, if any, of having the entire tooth a true involute was less than they would be led to believe by those advocating a change; indeed it was a matter yet to be demonstrated that the practical advantages of the form of tooth now in common use would not more than outweigh any theoretical advantages of a tooth wholly involute. The fact that the special requirements at the present time were for teeth varying both ways from the present standard would indicate that they now had a good average to meet ordinary working conditions. Their experience went to show that for quiet running for a possible variation in center distance and to avoid back-lash, a small pressure-angle and long teeth were of advantage, while for cases in which strength was the prime consideration, even at the sacrifice of other advantages, the greater pressure angle and shorter teeth had their field of usefulness. Those varying needs were illustrated in automobile practice, where in some makes the cam-shaft gears were made with a small pressure angle and long teeth, while the driving gear was made with a larger pressure angle and shorter teeth, in each case for the reasons he had previously referred to. That strength in the latter case was secured at some sacrifice was indicated by the illustration used by Mr. Gabriel in his communication, where he spoke of the injurious effects of the hammer-blow action when "stub-tooth" gears were used in street-car service. The same destructive action had been noticed in stub-tooth gears used for automobile service. An engineer who had for many years made a specialty of gearing, and who was an expert on that subject, and who had in recent years been with one of the leading automobile manufacturers of America, told him that he had repeatedly found the same destructive action spoken of by Mr. Gabriel when stub-tooth gears were used in various makes of automobiles.

2 Mr. Lewis, in referring to the preliminary tests made by the students of the Massachusetts Institute of Technology, said they showed that the loss by friction was varied to a greater extent by the length of the addendum than by the angle of obliquity.[1] As he understood, the tests to which Mr. Lewis referred were made entirely with roller bearings, thus reducing the bearing friction to a minimum. That friction, however, was one-third greater for the 20-deg. pressure angle than for the 14½-deg. angle. With plain bearings, where the friction on the bearing would be much greater than with roller bearings, that factor favorable to the smaller pressure-angle might more than offset any advantage shown by the tests in favor of the greater pressure-angle as reducing friction. As plain bearings were more extensively used than roller bearings, the tests could not be considered complete without securing full data when using plain bearings. He agreed fully with Mr. Gabriel as to the need of exhaustive tests by competent engineers before any result could be accepted as authoritative.

3 He wished to take the present opportunity of endorsing what Mr. Gabriel had said relating to other phases of the subject. He did not believe that any modification of the present standard which would require more cutters in a set to ensure good running gears would meet with favour among manufacturers, as it would add directly to the cost of the equipment. All of the plans suggested in Mr.

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[1] Given verbally by Mr. Lewis when presenting his paper.—EDITOR

Lewis's discussion were such as would require extra cutters in the set. Neither did he believe that any plan would be generally approved which would increase the amount of back-lash with a given variation in centre distance or with a given amount of wear. Unless some very important advantages could be shown for some new system yet to be suggested, it would seem unwise to bring about the confusion which would result from a change not fully endorsed by the manufacturing public.

Daniel Adamson[1] wrote that, as no doubt Mr. Steven's paper was intended to assist the proposed joint committee of the English Institution and The American Society of Mechanical Engineers, he thought that one or two important processes for the production of gearing, which were not mentioned, should be referred to. There was no mention of the Sunderland method of generating spur gearing, the machines for which were at present being made by J. Parkinson and Sons, Canal Iron Works, Shipley. In this system the cutter took the form of a rack, and it was found that gears could be cut very much more rapidly than by rotary cutters, and the further advantage was that the cutters were much simpler and cheaper. Only one cutter was required for any number of teeth of a given pitch and the teeth were all correctly cut, as distinguished from the rotary-cutter system, wherein each cutter was only correct for the exact number of teeth for which it was designed.

2 He thought it seemed hardly fair (at the bottom of p. 4) to quote as a "difficulty" the fact that gears produced in hobbing machines by hobs cut to Brown and Sharpe standard would be unsuitable for running with those cut to other standard shapes. This was the fault of the difference in the so-called "standards" and was not the fault of the hobbing method, but was in fact the main argument for an early standardization of all spur-teeth upon a definite system.

3 Coming to worm-gears, there was no mention of the Gibson system, which was described in the Proceedings of the North-East Coast Institution of Engineers and Shipbuilders in 1896-1897, Vol. 13. This system should certainly have some consideration, as he believed more worm-gears had been cut by this method and by the subsequently improved method introduced by Hy. Wallwork and Co., of Manchester, the licensees of the Gibson system, and known as the Wallwork-McClean method, than by any other system.

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[1] Messrs. Joseph Adamson and Co., Hyde, Eng.

4 In regard to the question of models of teeth (p. 6), there ought to be some consideration given to Lasche's paper in the Zeitschrift des Vereines deutscher Ingenieure for 1899, Vol. 43, wherein was described a system recommended by its author for the use of the A. E. G. This system was based upon a 15-deg. angle of pressure with an addendum of $1\frac{1}{2}$ module for the driver and $\frac{1}{2}$ module for the driven wheel, and bore some resemblance to the Bilgram system referred to in Wilfred Lewis's paper. There were many advantages claimed for it, namely, a stronger shape for the teeth of the pinion, a shorter arc of approach, and (when a rotary cutter was used) a more effective cutting shape, the radial flanks of the pinion teeth being very much shortened.

5 No paper on tooth gearing could be considered complete without at least a reference to Michael Longridge, Member of Council, who gave, in his annual reports for 1887-1888 and 1891, examples of very short teeth for large driving wheels. It was principally upon the basis of those reports that Mr. Adamson's firm adopted a shortened form of tooth in 1897, full particulars of which would be found in Vol. 24, issue No. 25 of the *American Machinist* of 1901, and which he was pleased to notice had the same length of addendum as the "stub-tooth" given in Table 1 of Mr. Steven's paper, namely, 0.25 of the circular pitch.

6 In conclusion, he sincerely trusted that the proposed joint committee would be encouraged by the discussion on these papers to push forward the important question of standardization of gear teeth, and to put it upon such a basis that satisfactory gear teeth could be produced in the future from a definite formula, without the use of any empirical correction.

THOMAS HUMPAGE[1] said that he thought much credit was due to Brown and Sharpe for standardizing their system of toothed gearing, which was known and used throughout the world. It was, however, introduced before the generating machine was in use, and it must give place to something better now. In view of the great advances that had been made during the past ten years in high-speed machinery owing to the introduction of high-speed steel and the great demand for silent running gears, the writer thought that we were undoubtedly behind the times in producing correctly-formed teeth to run quietly at these high speeds with great pressure, and he welcomed any improvements that might be adopted to attain this end. The Brown and Sharpe system should be left alone, as it would always be retained by certain manufacturers because it was good enough for their class of work.

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[1] Mem. I.M.E., Messrs. Humpage, Thompson and Hardy, Jacob St., Bristol, Eng.

2 The rack being the basis of all generated involute gears, the teeth should have straight sides, leaving the usual fillets at their roots below the working depth; and no deviation from this form should be made. A 12-tooth pinion should be the minimum for general purposes, because it has proved best in the past. For quietness and long life at high speeds, it was most essential that there should be no undercutting, and that the involute should extend to the whole working depth of the tooth. To generate these teeth on a 12-tooth pinion, the cutter or hob must have teeth with sides inclined at an angle of 22 deg., as a less angle would shorten the length of the involute and cause undercutting. As regards the addendum and dedendum, he quite agreed with Mr. Lewis's suggestions. These teeth could be generated on either of the following generating machines—an automatic hobbing machine, a Bilgram, Reinecker or Sunderland spur-gear planer, also on a Fellows gear shaper, providing the teeth of the cutter were ground to a true involute form down to the working depth of the teeth. They could also be cut on any machine of the Brown and Sharpe type with disc cutters made the exact shape of the space between the teeth. All wheels cut on these machines would then be interchangeable with each other. To facilitate repairs, it would also be a great advantage if manufacturers would stamp the pressure angle on the rims of the gears they cut, for example—14½ deg. Brown and Sharpe, or 22 deg.

3 It was, however, most unlikely that all the branches of the engineering trade using gears would accept any one standard pressure angle only. Taking the automobile industry, for instance, a 20-tooth minimum pinion was adopted by leading makers, and for change-speed gears a pressure angle of about 18 deg. would be sufficient to extend the involute to the working depth of the teeth without undercutting. It would also enable all existing machines in motor-car works to cut interchangeable gears, providing their cutters were formed on an 18 deg. angle basis.

4 An 18 deg. angle involute tooth was much stronger than the 14½ deg. Brown and Sharpe standard tooth, which was the one generally adopted by the motor-car manufacturers, and owing to the involute being extended the wheels would run more quietly and last longer. The outward pressure would, however, be slightly increased above

the Brown and Sharpe standard, but it would be less than a 22 deg. angle. Again, in the printing machine and many other industries, the smallest pinions had more than twelve teeth, and a pressure angle of less than 22 deg. would be a great advantage owing to the fact that, when wear had taken place there was not so much back-lash and the machines registered more accurately.

5 The above suggestions appeared to the writer to be the first steps in the right direction leading up to the far more important and the much-desired object of producing perfectly silent running gears. In the writer's paper on Spur Gearing, read before the Institution at the Summer Meeting in Bristol of July 1908, he described a method of grinding the involute teeth of gear wheels. Since then he had continued his experiments, which he believed to be the best way of producing correct involute teeth and silent-running gears, and hoped shortly to make the results known.

R. M. NEILSON[1] wrote that, in view of the necessity of having maximum efficiency and a small angle of pressure in many cases where high powers were required to be transmitted, as, for example, in the propulsion of ships, it would appear to be advisable to have two standard types of teeth—one being of a nature to allow of the teeth being cut with a disc cutter for any number of teeth per wheel down to about 12 (or possibly less than 12), while the other would be designed for maximum efficiency and contact and a small angle of pressure, but would not be of a nature to allow of execution by a disc cutter except for wheels having a relatively large number of teeth. To attempt to make one standard serve in all cases would force the employment of non-standard teeth in many cases.

J. R. WILLIAMS[2] wrote that in his opinion the suggested increase in the angle of pressure, although good, both from the interchangeable point of view and increased strength of the teeth, would have a tendency to form shoulders on the working base of the teeth; this would, of course, increase the pressure on the bearings to a greater extent than the theoretical pressure, due purely to the increased angle, and would have to be allowed for when calculating the bearing surfaces for the shafts.

[1] Mem. I.M.E., 45 Hope St., Glasgow, Scotland.

[2] Asso. Mem. I.M.E., Tramway Power Station, Kelham Island, Sheffield, Eng.

A COMPARISON OF LATHE HEADSTOCK CHARACTERISTICS

By Prof. Walter Rautenstrauch, Published in The Journal for June 1910

ABSTRACT OF PAPER

The paper is concerned with the determination of the adaptability of a number of engine lathes to the economic performance of a standard task. The method of comparison, devised by Dr. J. T. Nicolson and Dempster Smith, of Manchester, England, consists in determining the extent to which each speed-torque combination possible in a given lathe lends itself to removing the greatest weight of shavings in a given time from a given diameter of work. The standard task assigned to each lathe is taking a predetermined area of cut on all diameters of work of mild and soft steel pieces, with high-heat steels. The results of the comparison are not intended to justify or condemn a lathe for general purpose work, but to exhibit the attempts of different manufacturers to meet the conditions favorable to the use of the high-heat steels. They show, among other things, that a more rational means of spacing speed-torque combinations is needed. Many of the lathes examined are shown to have a number of speed-torque combinations which may be dispensed with, as far as their adaptability to more economic weight removal is concerned, no matter what the standard of comparison may be.

DISCUSSION

Carl G. Barth. Professor Rautenstrauch's paper interests me as an evidence of the new attitude of the university and college professors towards the problems of the practical engineer, for it is my impression that until recently they concerned themselves only with the most general theories except for machinery connected with the generation of power.

2 I regret to say, however, that the method of analysis adopted in this paper is hopeless as a means to the end in view, for the same reason that Mr. Taylor's labors for twenty years previous to the perfection of slide-rules for the scientific running of machine tools never fully resulted in what he was after, namely, a ready and accurate means of predetermining just how efficiently metal might be removed by a lathe or kindred machine tool from any piece of work at all fit to be handled in such a machine. This paper practically reattempts a theoretical solution of the basic part of the problem

Mr. Taylor and his earlier associates tried to solve, and that the present attempt has failed, except in calling attention to the desirability of a more wide-spread realization of both the problem and its solution, is indeed only natural.

3 The problem is too complex for any ordinary mathematical analysis and requires for its solution a slide-rule of the kind just referred to, on which the great number of constants and variables entering into the problem may be so happily arranged with relation to each other that the solution of any problem involving a part or all of these is solved by a moment's inspection.

4 Besides the impossibility of utilizing the method of analysis proposed in this paper for practical purposes, it would appear that the author has started out with a misconception of how a lathe is properly used in practice. He assumes that the cut a lathe is capable of taking on its full swing diameter is all that it is ever called upon to take, while the fact is that when used for the mere purpose of removing metal, a lathe is properly confined to work on diameters not exceeding the swing over its carriage, or even less. The maximum cut a lathe can take is limited only by the strength of the cutting tool when this is properly held in its post with a minimum of overhang. A lathe is therefore most efficiently utilized for roughing when the work routed to it is of such medium diameters and lengths that the maximum cut the tool can carry does not, on the one hand, put an undue stress on the weakest driving gear, nor, on the other hand, tend to spring the work beyond the elastic limit of its material.

5 Before taking steps to decide how low to make the minimum spindle speed of a lathe, it is therefore necessary to determine the maximum pressure to which we will subject its cutting tool and the ratio of this to the permissible pressure on the teeth of the largest spindle gear. From this is obtained the largest diameter on which the maximum cut can be taken which the tool itself will safely bear. Then can be determined the size of this cut and the cutting speed at which it may be taken on the hardest material on which it is intended to be taken and still have the tool last an economical length of time before burning out or wearing down to an undue degree without burning out, as for extra hard materials. Rarely, however, can the speeding of a lathe be determined with regard to roughing work only, since this is usually simply one of many factors that have to be considered.

6 To determine the size of motor to provide for a lathe, the softest

material on which it is desired to take the heaviest cut the tool will stand must be decided and the cutting speed at which this may be taken with an economical tool life. The minimum revolutions of belt-driven as well as motor-driven lathes and the size motor to provide for the latter are most readily determined by means of special slide-rules for the purpose, on the basis of the information bearing on the subject contained in Mr. Taylor's paper. On the Art of Cutting Metals, but approximate formulae for the purpose are easily developed.

The Author. It is to be regretted that the presentation of this paper has failed to call forth from the designers of lathes and similar machines a series of discussions which would throw additional light on the problem. It is hoped that this matter will not rest where it is, but that all having any knowledge of this subject will eventually contribute frankly and freely some item of value.

2 Mr. Barth's remarks are of much interest because of his long experience in this field. He does not confine himself to the body of the argument, however, although his contribution is of importance in that it presents a different point of view on what properly constitutes a basis for founding a method of comparison.

EXPERIMENTAL ANALYSIS OF A FRICTION CLUTCH COUPLING

By Prof. Wm. T. Magruder, Published in The Journal for January 1910

ABSTRACT OF PAPER

The paper gives the results of five lines of investigation on: (*a*) a dynamic clutch-testing machine; (*b*) a static apparatus, using 24-in. four-jaw friction clutch couplings from stock.

The solid clutch broke at 200 h.p. at 100 r.p.m., when the load was gradually applied, and at 110 h.p. at 100 r.p.m. for a pick-up load; the split clutch broke at 140 h.p. at 100 r.p.m. with the load gradually applied. A maximum axial thrust on the collar of 600 lb. may be required, or 115 lb. at the end of a one-to-five shifter lever, creating a total pressure of 8000 lb. by the shoes on the ring, or 50 lb. per sq. in.

DISCUSSION

H. J. Smith. The author gives three methods of making friction clutch tests:

- *a* Static test to determine the force required to cause the clutch to slip with a given force on the shifter lever.
- *b* The clutch in motion with the load gradually applied.
- *c* The clutch in motion with the load suddenly applied, to determine the pick-up load capacity of the clutch.

2 While the first two methods are interesting, the results do not apply directly to actual working conditions. The pick-up test alone determines the capacity of the clutch and its factor of safety. Both experience and the results of numerous tests show that the pick-up load is extremely variable, depending on the class of work. In some instances in actual practice it is more than 210 per cent above the normal running load of the clutch. From this it is evident that both in the rating and in the selection of a clutch for a given service, the pick-up load is the controlling factor.

3 When a clutch under test has its load gradually applied, the transmitting capacity of the clutch is at its best, and its factor of safety highest. When called upon to pick up a dead load suddenly, the effect on the clutch is that of impact, and the factor of safety is reduced very often to a dangerous degree.

4 It will be seen from test I in Table 1 of the paper, the only recorded tests upon a split clutch, which is the weaker type of construction, that with a gradually-applied load the clutch transmitted 146 h.p. and broke. The stronger construction—the solid clutch—carried 187 h.p. and broke. Now note that this latter solid clutch carried only 102 h.p. on a suddenly applied, or "pick-up" load, and broke.

5 On the basis named by the author for gradually applied loads, that the four-arm split clutch will carry 78.5 per cent of the breaking load carried by the four-arm solid clutch, the split clutch would have broken on a pick-up load of about 80 h.p. This is in line with extensive prony brake tests made by me in 1908 and 1909, which showed for pick-up loads that 80 h.p. at 93 r.p.m. is about the rupture capacity of 24-in. split clutches and about 100 h.p. for 24-in. solid design clutches, as made by different manufacturers.

6 I must, however, take exception to the author's final conclusion that a factor of safety of 10 exists in clutch manufacture. This is far too high. In the first place the coefficient of rest is greater than the coefficient of motion, and we must not forget that the transmitting capacity of a clutch is dependent upon its ability to pick up its load from rest. In practice the dead load of the prony brake is replaced by the friction and inertia of large masses, such as occur in starting into motion long lines of shafting, flywheels, pumps, attrition mills, ball mills, tube mills, or other similar machinery.

7 During the time of slippage under the pick-up loads the coefficient of friction is lowest and the wear on the wood shoes greatest. Once in motion the friction of rest, which exists between the clamped members of the clutch, insures the continued transmission of any load that can be picked up.

8 In the second place the rating of a clutch of any size should be based on the split construction. In the test under consideration the rupture capacity of the 24-in. split clutch is about 90 h.p. at 100 r.p.m. The rating of the makers is 19 h.p. at the same speed. The factor of safety, therefore, is less than five.

9 In all tests made by me the final rupture occurred at the keyway of the clutch hub; the bolting lugs and bolts gave way at the same moment and the ring was broken only by the thrust of the broken clutch mechanism.

10 There is no doubt that the transmitting capacity of a clutch increases practically proportionately with the number of arms; on the other hand it is equally certain, from a study of design, that the factor of safety will vary with the number of arms. My own opinion

of the factor of safety of a Hill clutch of four-arm construction is that each arm, independent of the others, should be able to carry safely the rated capacity of the clutch at 100 r.p.m. This gives a factor of safety of four. For a three-arm clutch in the same manner the factor of safety is three, but for a six-arm clutch it rarely exceeds four. This is because a six-arm clutch has a no stronger hub construction than a four-arm clutch on account of the congested design.

11 In a series of tests by Prof. R. G. Dukes of the Case School of Applied Science, Cleveland, results were obtained upon the ultimate capacities of different types and makes of clutches. In the following table is given the performance of a 24-in. split positive-action Hill clutch, which, however, was not pushed to its greatest capacity on account of lack of power on the testing stand:

TABLE 1 TESTS ON 24-IN. POSITIVE ACTION HILL CLUTCH
CATALOGUE RATING 48 H.P. AT 100 R.P.M.

Number of Test	Thrust on Collar, lb.	Maximum Brake Load, lb.	Horsepower at 100 r.p.m.	Remarks
1	258	540	74	Clutch slipped
2	334	830	113	Clutch slipped
3	410	880	120	Clutch slipped
4	544	1030	141	Limit of Testing Stand

12 To illustrate the enormous power-transmitting capacity of the ring type of clutch, the following test is of interest. It was made on a 24-in. No. 60 Smith type Hill split clutch of very heavy construction. It is rated at 60 h.p. at 100 r.p.m. Fig. 1 shows the design of the clutch, which is positive in its action, no springs being required for disengaging the jaws.

13 The test was conducted as follows: The power transmitted was measured by a prony brake and platform scales. The speed of the clutch shaft was maintained at 93 r.p.m. A spring scale measured the force applied to the hand lever. The wood shoes were first worn to a fit on the ring. Then the jaws were adjusted so that a certain pressure on the hand lever engaged the clutch. Next the brake band was tightened and the clutch engaged, forcibly picking up the dead load from rest. Repeated trials gave the maximum brake load which the clutch would pick up without slipping. When a slip occurred the jaw adjustment was increased to give larger hand lever scale readings, and corresponding higher brake readings. The final read-

ing of the transmitting capacity was limited only by the available power. The results are given in Table 2.

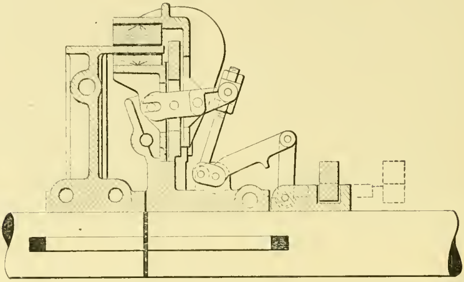

Fig. 1 24-in. No. 60 Hill Split Clutch (Smith Type)

14 It will be noted that these results were obtained with a split clutch starting from absolute rest—the true pick-up load—and bringing up to speed at the stated loads. No breakage occurred. It is the result of correct toggle action and rigidity of construction.

TABLE 2 TESTS ON 24-IN. NO. 60 HILL SPLIT CLUTCH (SMITH TYPE)

Catalogue Rating 60 h.p. at 100 r.p.m.

Number of Test	Thrust on Collar, lb.	Net Maximum Brake Load, lb.	Horsepower at 100 r.p.m.	Remarks
1	188	365	58	Clutch slipped on further tightening brake
2	258	527	84	
3	312	728	116	
4	380	878	140	
5	456	1087	173	
6	740	1430	228	Limit of testing stand

Prony Brake Arm 100-in. long.

15 It is of interest to note also that the ring type clutch described in the paper was the invention of Harry W. Hill (February 10, 1885). In its fundamental construction two members are required: a toggle-locked friction clamp and a friction ring. To preserve the balance of the clutch and increase its capacity, additional friction clamps are added, making two, three, four or six arm clutches.

G. N. VanDerhoef. The real point in connection with friction clutches is undoubtedly the picking-up of the load, and these tests seem to lack in that they do not give the mass that is started from rest and the time required to accelerate it to uniform velocity. That is the duty the clutch has to perform and is the real measure of the strength of the clutch. The time should be given in seconds, or in fractions of seconds. When this is done we will have some idea of the relative value of friction clutches.

H. J. Smith. In regard to the time element in tests of friction clutches, I know that in Professor Duke's report and in the tests I conducted myself, it was found best to throw in the clutch just as rapidly as possible. In any case, on a pick-up load, clutches of all types were thrown in as quickly as it could be done by the impulse of two men on the hand lever.

E. P. Haines. In connection with the time taken to start a load, take the case of a gas engine in a machine shop. If the clutch is thrown in quickly, the gas engine will stop, and if it is thrown in too slowly, the clutch will burn out unless it has ample surface to prevent overheating. The time taken to apply the load should be between the two extremes.

H. J. Smith. Through this system of testing I have evolved the following rules: for single-cylinder gas engines, use a clutch of double the capacity at a given speed; for double and triple-cylinder gas engines, use one rated at from 25 to 50 per cent above the capacity desired; with engines of four or more cylinders, use a clutch of the rated capacity for steam engine practice.

Oberlin Smith said that clutches should always be thrown in as quickly as possible, especially if they have wooden or fiber shoes, except where gas engines are used for power. He has found that clutches as a rule are built too small in diameter, necessitating severe clamping to obtain sufficient friction to carry the load. This is sometimes necessary where the diameter must be restricted, but in general large diameter should be employed to obtain speed and to reduce the pressure on the clamps. He stated that his experience had been mostly with clutches used for starting presses, where the inertia of large shafts and heavy chains of gearing impose severe strains on them. Under such conditions the clutch surface is run at the highest safe speed, about a mile a minute, in order to obtain the greatest benefit from the friction.

2 Many of the friction clutches in the market are excellent but complicated. They require a great deal of mechanism to give enormous pressure at the friction surface. For driving heavy presses a much simpler form of clutch is preferable and the old cone form has been adopted. By making the surface wide and large in circumference a very simple toggle mechanism is sufficient.

The Author. In reply to H. J. Smith's remarks, I would say that every one is aware that a split pulley is not as strong as a solid one, and for that reason the number of split friction clutch-couplings sold is probably less than ten per cent of the number of solid ones made and sold.

2 In reply to Mr. VanDerhoef, it should be said that the mass that was started from rest is shown in Fig. 2. The 48-in. by 24-in. brake pulley weighed about 2800 lb. No automatic and autographic apparatus was available for recording the time required suddenly to apply the load. The instructions were to throw the load on as quickly as possible, and this was done. To describe this action as accurately as possible, it is called in Table 5 a suddenly applied load rather than a pick-up load. Just what fraction of a second this was each one can judge from his own experience. The term pick-up load is quite indefinite as to the time element and simply describes the starting into motion of a shaft, etc., which was at rest and with an indefinite amount of slipping of the friction members.

3 Replying to Oberlin Smith, I would say the intensity of pressure of the shoes on the ring was about 50 lb. per sq. in. with this clutch (see Par. 37 *Bd*).

TEST OF A 15,000-KW. STEAM-ENGINE-TURBINE UNIT

By H. G. Stott and R. J. S. Pigott, New York

This paper was published in The Journal for March 1910 and relates to tests of low-pressure steam turbines installed at the 59th Street Station of the Interborough Rapid Transit Company of New York, originally equipped with engines of the Manhattan type to which vertical low-pressure turbines and independent generators were added. The discussion upon the paper presented at the meeting and contributed later was published in The Journal for August. The following addition to the discussion is given by the author in reply to an inquiry as to the advisability of installing a new plant with a combination unit of engine and turbine.

The Author. In reply to the question by Max Rotter as to whether it would be advisable to install in a new plant such a combination as described in the paper, the accompanying diagram (Fig. 1), showing the factors entering into the cost of power, will answer his question. For example, with a low load factor, it is quite evident that the all-important point is to keep down the fixed charges for when the load factor is less than 20 per cent, the fixed charges are of vastly greater importance than any possible gain of efficiency due to a better type of prime mover. This is true of any plant, and the curve shows the futility of attempting to carry peak loads by means of gas engines, water power or any other prime mover necessitating a large investment per kilowatt. On the other hand, with loads having a load factor of over 60 per cent especially where fuel cost is high, the investment factor is of relatively small importance, and the all-important matter is to keep down the maintenance and operating charges by using the most efficient type of plant obtainable, provided that it is at the same time thoroughly reliable.

2 The total cost of power can be obtained from these curves by simply taking the sum of the ordinates above and below the axis for any load factor desired..

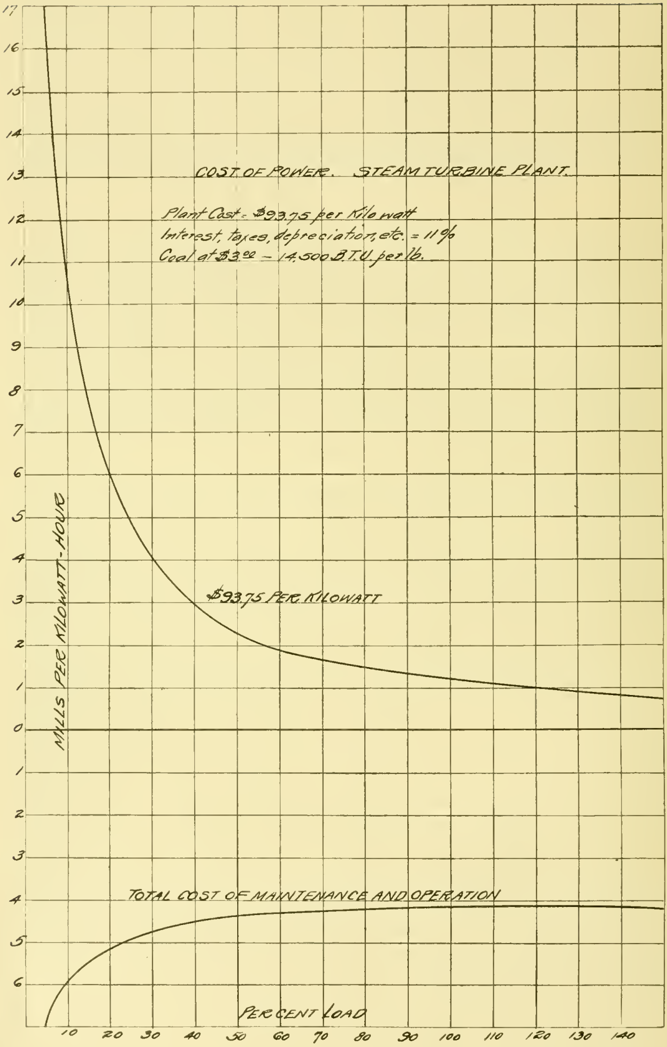

Fig. 1 Test of a 15,000-kw. Steam-Engine-Turbine Unit

Diagram of Factors entering into the Cost of Power

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

At the monthly meeting of the American Society of Civil Engineers, held on September 21, 1910, papers were presented on Long Island Approaches to the East River Tunnel, on The Sunnyside Yard, and on The Lining on the Four Permanent Shafts of the East River Tunnel.

AMERICAN SOCIETY OF ENGINEERING CONTRACTORS

The annual convention of the American Society of Engineering Contractors was held in St. Louis, Mo., September 27–29, 1910, in the Coliseum. Papers were delivered by J. B. Goldsborough and Edward Wegmann, both of New York, on Dam Construction for City Water Supplies; and by George C. Warren, of Boston, on Work Preliminary to Street Paving and Road Work. A banquet was held during the convention and several sightseeing trips made to important engineering works in and around St. Louis.

NEW ENGLAND WATER WORKS ASSOCIATION

The twenty-ninth annual convention of the New England Water Works Association was held at Rochester, N. Y., September 21–23. Among the papers presented were: Pertinent Matters Relating to Water Works, Frederick Eltwood; Purification Plant of Rochester and Lake Ontario Water Company, Rochester, N. Y., James M. Caird; Depreciation in Water Works and Methods of Accounting therefor, Leonard Metcalf, Mem.Am.Soc.M.E.; The Use of the Water Ejector for Transporting Sand, Morris Knowles, Mem.Am.Soc. M.E., and John M. Rice.

NEW YORK RAILROAD CLUB

The first regular meeting of the New York Railroad Club for the fall season was held Friday evening, September 16, in the Engineering Societies Building, 29 West 39th Street. B. S. Hinckley, Engineer of Tests of the New York Central and Hudson River Railroad, presented a paper entitled the Testing Department of a Railroad.

NATIONAL ASSOCIATION OF GERMAN-AMERICAN TECHNOLOGISTS

The twenty-sixth annual convention of the National Association of German-American Technologists was held at Newark, N. J., September 1–5. Dr. L. H. Friedburg presented a paper on The Activity of Radium and Permanency of the Element with Side-Lights on Transmutation and Alchemy. Excursions were made to the Edison Laboratory, West Orange, N. J., and to the Henry R. Worthington Hydraulic Works, Harrison, N. J.

ASSOCIATION OF RAILWAY ELECTRICAL ENGINEERS

At the convention of this association, held September 27–30 at the La Salle Hotel, Chicago, Ill., papers were presented on the following subjects: Electric Lighting of Railway Cars, Axle Generating Systems, Electric Traction on Trunk Lines, Motor Driven Machine Tools, and The Illumination of Railway Passenger Stations and Machine Shops.

ROADMASTERS AND MAINTENANCE OF WAY ASSOCIATION

The twenty-eighth annual convention of the Roadmasters and Maintenance of Way Association was held at the Great Northern Hotel, Chicago, Ill., September 13–16, with an attendance surpassing all former records. The following subjects were discussed: Proper Care of Track Material and Tools; Cattle Guards; New and Improved Appliances, including Ties; Standard Switch Target; Rail Fastenings, including Insulated Joints; Tie Plates and Anchors. A paper on Treated Timber was presented by J. L. Single.

THE COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION

The eighth annual convention of the Colorado Electric Light, Power and Railway Association was held at the Hotel Colorado, Glenwood Springs, Colo., September 21–23, and was the largest and most interesting meeting from a professional point of view that the association has ever held. Papers were read on the following subjects: Storage Batteries in Street Railway and Central Station Work, F. A. Warfield; Some Observations on Cultivating Friendly Relations with the Public, J. M. Connelly; Mazda Street Series Lighting, R. L. Jones; High and Low Tension Lines, J. C. Lawler; The Place of Rotary Condensers and Induction Generators in Transmission Systems, H. L. Aller. Reports were also received from committees appointed to investigate the Subject on Grounded Secondaries, Meters, Insurance, etc.

PERSONALS

E. T. Adams has resigned as chief engineer and manager of the gas and mill engine department of the Allis-Chalmers Co., West Allis, Wis., a position which he has held for the past five years.

H. P. Ahrnke has become associated with the Barrett Manufacturing Co., New York. He was formerly identified with the Pa. Tunnel & Terminal R. R. Co., New York.

Jos. E. Aue has become identified with the Snow Steam Pump Works, Buffalo, N. Y. He was formerly connected with the Pacific Gas and Electric Co., San Francisco, Cal.

Earle J. Banta, chief engineer of the Ohio Steam Shovel & Dredge Co., Cincinnati, O., has resigned his position to accept a similar position with the Vulcan Steam Shovel Co., Toledo, O.

Harry Z. Bixler has entered the employ of the Youngstown Steel Co., Youngstown, O., as chief engineer. Until recently he was associated with Worth Brothers Co., Coatesville, Pa.

Joseph B. Brady has resigned as assistant experimental engineer of the Hess-Bright Manufacturing Co., Philadelphia, Pa., to take up studies in electrical engineering at Purdue University, Lafayette, Ind.

Joseph Breslove recently associated with the engineering department of the Westinghouse Machine Co., Pittsburg, Pa., has been appointed mechanical engineer of the Nivison-Weiskopf Co., Cincinnati, O.

John F. Buckley, formerly general superintendent of the St. Marys Machine Co., St. Marys, O., has become general manager of the Buckley Specialty Co., Lima, O.

Carl F. Dietz of the firm of Dietz & Keedy, Boston, Mass., has returned from Europe.

John A. Doane, formerly superintendent of shops of the Taylor Iron & Steel Co., High Bridge, N. J., is now associated with the American Optical Co., Southbridge, Mass., in a similar capacity.

Henry L. Doherty has resigned as president of the American Gas & Electrical Co He remains a director.

A. Hartill-Law, has been elected Mayor of Cairus, North Queensland.

J. E. Johnson, Jr., until recently general superintendent of the Thomas Division of the Republic Iron & Steel Co., Thomas, Ala., has accepted a position with the Lake Superior Iron & Chemical Co., Ashland, Wis., as manager.

Edward J. Kunze, formerly instructor in steam and gas engineering, University of Wisconsin, Madison, Wis., has been appointed assistant professor of mechanical engineering at the Michigan Agricultural College, East Lansing, Mich.

A. Lebrecht has resigned his position as chief engineer of the gas and oil engine department of the De La Vergne Machine Co., New York, N. Y., and has opened an office as consulting engineer in Nuremberg, Germany.

Ralph D. Mershon was elected president of the Alumni Association of the Ohio State University for the ensuing year.

Arthur F. Pitkin has accepted a position with the General Electric Co., Schenectady, N. Y., as assistant to the mechanical superintendent. He was formerly standard practice engineer of the automobile department of the American Locomotive Co., Providence, R. I.

H. F. J. Porter has been engaged during the past summer in an investigation of hygienic conditions and their effect on the efficiency of the employees in manufacturing establishments in Pittsburg for the Russell Sage Foundation.

L. R. Shallenberger, until recently superintendent of construction for the Griffin Wheel Co., with headquarters at Chicago, Ill., has opened an office in Paonia, Colo., for general engineering work.

P. S. Steenstrup, formerly general sales manager of the Hyatt Roller Bearing Co., Harrison, N. J., also secretary and director of the Motor and Accessory Manufacturers, has incorporated the Wayne Pacific Distributing Co., with general office in Medford, Ore., and with warehouses in Portland, Ore., and San Francisco, Cal.

H. Struckmann, until recently chief engineer and general manager of the Union Sand & Material Co., St. Louis, Mo., has become associated with the Iola Portland Cement Co., Iola, Kansas, in a similar capacity.

James W. Thomas, formerly of the engineering staff of Westinghouse, Church, Kerr & Co., New York, has been appointed mechanical engineer of the New England Engineering Co., New York.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

L'AEROPHILE. Years 16 and 17, Nos. 1-21, 23-24. *Paris, 1908-09.* Gift of A. W. H. Griepe.

BOILER TROUBLES AND THEIR TREATMENT. By George W. Lord. *Philadelphia, 1910.*[1]

CATALOGUE OFFICIEL DES COLLECTIONS DU CONSERVATOIRE NATIONAL DES ARTS ET MÉTIERS. Pts. 4 and 6, 1908, 1910. *Paris, 1908, 1910.* Gift of Conservatoire National des Arts et Metiérs.

COLORADO SCIENTIFIC SOCIETY. Yearbook, 1882-1910. *Denver, 1910.* Gift of the society.

CONGRÈS (PREMIER) INTERNATIONAL DU FROID, PARIS, 1908. Comptes Rendus. Vols. 1-3. *Paris, 1908.*

THE ENGINEER. Published by the Engineering Students of the Pennsylvania State College. Vol. 3. No. 3. April 1910.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS. Twenty-fifth annual report. 1910. *Chicago, 1910.* Gift of the society.

EIN JAHR VERBAND DEUTSCHER DIPLOM-INGENIEURE. By Alexander Lange. Sonderabdruck Zeit. des Verbandes Deutscher Diplom-Ingenieure, pt. 16, 1910. *Berlin.* Gift of the author.

MCGILL COLLEGE AND UNIVERSITY. Annual Calendar, 1910-1911. *Montreal, 1910.* Gift of the university.

METALLOGRAPHIE. By W. Guertler. Vol. 1. No. 4. *Berlin, Borntraeger, 1910.*

MOTOR UNION JOURNAL. Vol. 2. No. 6. July 1910. *London, 1910.*

OHIO ELECTRIC LIGHT ASSOCIATION. Programme, 16th annual convention, July 26-28, 1910, Cedar Point, Ohio.

ORGAN FÜR DIE FORTSCHRITTE DES EISENBAHNWESENS. General Index. Vol. 1-44. 1864-1907. *Wiesbaden, 1873-1908.*

PENNSYLVANIA, COLONIAL AND FEDERAL. A History. 1608-1900. Edited by H. M. Jenkins. *Philadelphia, 1902.*

RESISTANCE DE L'AIR. By G. Eiffel. *Paris, 1910.* Gift of the author.

SCHWEIZERISCHER INGENIEUR UND ARCHITEKTENVEREIN MITGLIEDERVERZEICHNIS. 1909. *Zurich, 1909.* Gift of the society.

SOCIETY FOR THE PROMOTION OF ENGINEERING EDUCATION. List of the Officers and Members, April, 1910.

SOCIETY OF ENGINEERS OF EASTERN NEW YORK. List of Members, 1910. *Albany, 1910.* Gift of the society.

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[1] **Corrected Title. Published incorrectly in The Journal for July.**

TECHNIK UND WIRTSCHAFT. Yr. 1, pts. 1-5, 7-12. *Berlin, 1908.* Gift of A. W. H. Griepe.

TECHNIKER IN DER MODERNEN STAATSWIRTSCHAFT. By Alexander Lang. Sonderabdruck aus dem Zeit. des Verbandes Deutscher Diplom-Ingenieure, Pt. 1, 1910. *Berlin.* Gift of the author.

TRAVELING ENGINEERS ASSOCIATION. Report of 18th annual meeting Niagara Falls, Can., Aug. 16-18, 1910. Gift of the association.

JAMES WATT'S CONTRIBUTION TO THE ADVANCEMENT OF ENGINEERING. By Robert Caird. From Papers of the Greenock Philosophical Society. *Greenock, 1910.* Gift of the author.

WISCONSIN GAS ASSOCIATION. Proceedings. 1910. *Milwaukee, 1910.*

EXCHANGES

AMERICAN SOCIETY OF CIVIL ENGINEERS. Transactions. Vol. 68. *New York, 1910.*

INSTITUTION OF CIVIL ENGINEERS. Minutes of Proceedings. Vol. 180. *London, 1910.*

JIGS AND FIXTURES. By Einar Morin. Pts. 1-3. *New York, 1909.*

MEMORIAL DU GÉNIE MARITIME. Ministère de la Marine. Dec. 1908, May and June 1910. *Paris, 1910.*

NATIONAL ASSOCIATION OF COTTON MANUFACTURERS. Transactions. No. 85. *Boston, 1909.*

TRADE CATALOGUES

ALLIS-CHALMERS CO., *Milwaukee, Wis.* Bull. No. 1054. Steam Turbines and Generators, 43 pp.

H. G. BARR, *Worcester, Mass.* Multiple spindle sensitive drilling machines, 2 pp; Drilling and tapping machines, 1 p.

BROWN HOISTING MACHINERY CO., *Cleveland, O* Modern ore and coal handling machinery, 80 pp.

CLEVELAND AUTOMATIC MACHINE CO., *Cleveland, O.* Automatic machines, attachments and tools, 114 pp.

CONSOLIDATED SAFETY VALVE CO., *New York.* Safety valve capacity with tables of capacities of safety valves, by P. G. Darling, 31 pp.

HESS-BRIGHT MFG. CO., *Phila, Pa.* Adapter bearings for radial loads on line shafts, 1 p; Marine propeller ball bearing thrust block, 1 p.

IDEAL ELECTRIC & MFG. CO., *Mansfield, O.* Bull. No. 1051. Revolving field alternators, 11 pp.

JOHNS-MANVILLE CO., *New York.* Roofing Salesman, Aug. 1910, 8 pp.

LINK-BELT CO., *Phila, Pa.* Peck carrier for conveying of coal and ashes in power houses, 96 pp.

NATIONAL ELECTRIC LAMP ASSOC., *Cleveland, O.* Bull. 9 A. Cost of Light, by S. E. Doane, 19 pp; Bull. 12. Electric Lighting of Automobiles, 23 pp.

NILES-BEMENT-POND CO., *New York.* Progress Reporter, June 1910, 20 pp.

JOSEPH T. RYERSON CO., *New York.* Stock list of iron and steel supplies, 144 pp.

UNDERFEED STOKER CO. OF AMERICA, *Chicago, Ill.* Publicity Magazine, July and August, 30 pp.

VEEDER MFG. CO., *Hartford, Conn.* Odometers and tachodometers for automobiles, 15 pp; Counters for machines, cash registers, and other automatic machines, 31 pp; Castings, 14 pp; Cyclometers for bicycles and motorcycles, 16 pp.

WATSON-STILLMAN CO., *New York.* Twin volute turbine pumps, 76 pp.

WHEELER CONDENSER & ENGRG. CO., *Carteret, N. J.* Bull. 106. High vacuum surface condensers for steam turbines, 19 pp.

R. D. WOOD & CO., *Phila, Pa.* Theissen patent centrifugal contra-flow gas washer, 23 pp.

UNITED ENGINEERING SOCIETY

ENGINEERING RECORD. Vol. 24. *New York, 1891.*

KANSAS GAS, WATER, ELECTRIC LIGHT & STREET RAILWAY ASSOCIATION. 12th annual meeting, Wichita, Kan., Sept. 23-24, 1909. Gift of the association.

MICHIGAN GAS ASSOCIATION. Proceedings of the 18th annual meeting, 1909. Gift of the association.

MUNICIPAL ENGINEERING. Vols. 22-23. *New York, 1902.*

SANITARY ENGINEER. Vols. 12, 16. *New York, 1885, 1887.*

STATEMENT OF FACTS CONCERNING THE SO-CALLED BARCROFT APPRAISAL OF THE DETROIT UNITED RAILWAY LINES IN THE CITY OF DETROIT, AUGUST 1910. Gift of R. B. Rifenbcrick.

STATESMAN'S YEARBOOK, 1910. *London, Macmillan & Co., 1910.*

SURVEYORS INSTITUTION. List of Members, 1910. *Westminster, 1910.* Gift of the institution.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

047 Wanted by foundry and machine company near New York several capable estimators and draftsmen. Opportunities to advance in engineering department or to other departments.

048 High grade designing draftsman with large experience in steam engineering practice, for a permanent position with large manufacturing concern in Massachusetts. State age, education, experience and salary expected.

049 Instructor, machine drawing and design. Initial salary $1000 to $1200 for seven months, promotion assured to right man. Candidate should have good experience in shop and drafting room. Department M. E., School of Mining, Kingston, Ont., Canada.

050 A young man to assist in engineering department, $850 for the college year to start. Should have some drafting room experience, besides a college degree; work involves gas engine design. Would prefer to have man who has had some experience in this line. University of Minnesota.

MEN AVAILABLE

116 Mechanical engineer, practical technical graduate, at present employed as factory superintendent in an eastern manufacturing concern, would consider an opening in a similar capacity or in general engineering work.

117 Member, technical graduate, charge of large shops as superintendent and manager, also estimating cost systems, correspondence, etc., thorough experience in design, construction and economical operation of power and manufacturing plants. Several years experience as sales manager Corliss engines; also as general sales manager Water Tube Boilers. Desires position with chance to secure an interest. Engaged in special work at present but desires permanency.

118 Member, age 35, practical mechanic, technical education Cornell University, desires position as general superintendent or works manager, good hustler and organizer. Experience with the heaviest class of machinery.

119 Mechanical engineer, graduate of M. I. T., five years practical experience, three years chief engineer manufacturing concern, desires a responsible position with good opportunities for advancement. At present employed.

120 Mechanical engineer, fourteen years experience, heating, ventilating, power plant, gas engine and gas producer, machine tools; general engineering experience covers shop, drafting room, selling and experimental station, factory methods and system. Inventive and executive ability; speaks English, German and French. Salary, $2000. New York City or vicinity.

121 Junior, 30, seven years as draftsman and designer of gas engines, large units, mining and special machinery. One year systematizer, six months assistant master mechanic over maintenance gang of one hundred; six months secretary of refrigerating air-machine company. Has executive ability, successful with help, adaptable, ingenious, resourceful.

122 Young engineer, Stevens graduate; specialized in power plant equipment, condensers and cooling towers, desires position leading to administrative responsibility.

123 Young engineer, Stevens graduate. Recently assistant to consulting civil engineer. Would like position with manufacturing concern. Junior Member.

124 Member, 30 years experience, designing, constructing, selling and installing general machinery for factories, railroads and sugar plantations, in Cuba, Mexico and South America, desires position of responsibility with company requiring service of experienced mechanical engineer. Speaks Spanish and is familiar with export business.

125 Junior Member, technical graduate, eight years experience in engineering and manufacturing, at present chief draftsman in large manufacturing concern in Michigan, desires position in the East.

126 Member having extensive executive and mechanical experience desires to secure a position in Greater New York as sales or purchasing engineer; large experience in designing, selling and buying sugar machinery.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ABRAHAMS, M. Landa (Junior, 1910), U. S. Engr.'s Office, Federal Bldg., Chicago, Ill.

ADAMS, Edward T. (1899), Milwaukee Club, Milwaukee, Wis.

ADAMS, Kilburn E. (Junior, 1908), Mech. Engr., Boston & Albany R. R., Rm. 372, South Sta., Boston, and *for mail*, 629 Watertown St., Newtonville, Mass.

AHRNKE, H. P. (Junior, 1902), Barrett Mfg. Co., 17 Battery Pl., New York, N. Y.

AUE, Joseph E. (1899), Snow Steam Pump Wks., Buffalo, N. Y.

AUTENRIETH, George C. (Junior, 1908), Instr., Descriptive Geometry and Drawing, College of the City of N. Y., New York, N. Y., and *for mail*, 5 Duer Pl., Highwood Park, Weehawken, N. J.

BANTA, Earle Jackson (1907), Ch. Engr., Vulcan Steam Shovel Co., Toledo, O.

BENNET, Orville G., Jr. (Junior, 1907), Okonite Co., 253 Broadway, New York, N. Y.

BLAKE, Clinton F. (1901), R. F. D. 6, Box 112, Oregon City, Clackamass Co., Ore.

BRADY, Joseph Benjamin (Junior, 1910), 218 Fowler Ave., West Lafayette, Ind.

BRAMAN, Samuel N. (Junior, 1902), 10 Newbury St., Boston, Mass.

BUCKLEY, John Francis (1906), Genl. Mgr., Buckley Specialty Co., Lima, O

DAMON, Walter Henry (1909), Supt. of Generating, United Elec. Light Co., 32 Bancroft St., Springfield, Mass.

DAY, Charles (Junior, 1902), Member of Firm, Dodge, Day & Zimmermann, Engrs., Wash. Bldg., 608 Chestnut St., Philadelphia, and 5021 Schuyler St., Germantown, Philadelphia, Pa.

DOANE, John Appleton (1910), Supt. of Mch. Shops, Am. Optical Co., Southbridge, Mass.

DODGE, Kern (Junior, 1902), Member of Firm, Dodge, Day & Zimmermann, Engrs., Wash. Bldg., 608 Chestnut St., Philadelphia, and 5135 Pulaski Ave., Germantown, Philadelphia, Pa.

DREYFUS, Theo. Frank (Junior, 1903), 895 W. Bancroft St., Toledo, O.

EVANS, Henry O. (1896), Contr. and Designing Engr. of Special Mchy., 566 Drexel Bldg., Philadelphia, Pa.

FLAGG, Stanley G., Jr. (1891), S. G. Flagg & Co., Morris Bldg., 1421 Chestnut St., Philadelphia, Pa.

FLETEMEYER, Louis H. (Junior, 1906), Ch. Draftsman, Canada Fdy. Co., Ltd., and *for mail*, 519 Brock Ave., Toronto, Ont., Canada.

FROST, Harwood (1910), 1636 Monadnock Blk., Chicago, Ill.

GREUL, W. Herman (1907), Otis Elev. Co., 17 Battery Pl., New York, N. Y.

HAGAR, Arthur Percy (Associate, 1907), Engr., Marine Dept., Safety Car Htg. & Ltg. Co., 206 Erie St., Jersey City, and *for mail,* 716 Cliften Ave., Newark, N. J.

HANSEN, T. H. C. (1905), Wire Specialty Wks., 549 Fulton St., and *for mail,* 2429 Leland Ave., Chicago, Ill.

HAZELTON, William S. (1909), 247 Hancock Ave., E., Detroit, Mich.

HENDERSON, Geo. R. (1890), Cons. Mech. Engr., 500 N. Broad St., Philadelphia, Pa.

HENES, Harry W. (Junior, 1909), A. Bolter's Sons, Structural Steel, Rm. 612, 84 La Salle St., Chicago, Ill.

HIBBARD, H. Wade (1891; 1894), Prof. Mech. Engrg., Univ. of Mo., 1307 Kaiser Ave., Columbia, Mo.

HILL, Alfred J. (Associate, 1902), 1330 Castillo St., Santa Barbara, Cal.

JOHNSON, J. E., Jr. (1896; 1901), Mgr., Lake Superior Iron & Chem. Co., Ashland, Wis.

KEELY, Royal R. (1901; 1907), Prof. Elec. Engrg., Nova Scotia Tech. College, Halifax, N. S.

KING, Roy Stevenson (1904; 1910), 252 Jefferson St., Valparaiso, Ind.

KUNZE, Edward J. (1907), Asst. Prof. Mech. Engrg., Michigan Agri. College, East Lansing, Mich.

LANGLOTZ, Robert (1894; Associate, 1904), 78 Delevan St., and *for mail,* 396 Third St., Brooklyn, N. Y.

LARNER, Chester W. (Associate, 1907), Hyd. Engr., Wellman-Seaver-Morgan Co., Cleveland, O.

LAUER, Conrad N. (Associate, 1903), Mgr., Dodge, Day & Zimmermann, Wash. Bldg., 608 Chestnut St., and 2217 Estaugh St., Philadelphia, Pa.

LEBRECHT, A. (1910), Cons. Engr., Hefnersplatz 3, and Bayrentherstrasse 22, Nuremberg, Germany.

LEEPER, Ralph W. (Junior, 1908), Genl. Elec. Co., Provident Bank Bldg., Cincinnati, O.

LEVIN, Arvid Michael (1894), Mech. Engr., 864 Monadnock Bldg., Chicago, Ill.

LINDSAY, W. Edward (1895), Cons. Engr., 1 S. 20th St., and *for mail,* P. O. Box 196, Birmingham, Ala.

MILLER, Frank Louis (Associate, 1907), Erecting Engr., Southwark Fdy. & Mch. Co., Philadelphia, Pa.

MILNE, James (1907), Cons. Engr., Windsor, Ont., Canada.

PEDDLE, John Bailey (1909), Prof. Mch. Design, Rose Poly. Inst., and *for mail,* 2117 N. 10th St., Terre Haute, Ind.

PITKIN, Arthur Frederick (Junior, 1907), Asst. Mech. Supt., Genl. Elec. Co., Schenectady, N. Y.

RAY, David H. (Associate, 1904), Instr., College of the City of N. Y., 140th St. and Convent Ave., and *for mail,* 329 Edgecomb Ave., New York, N. Y.

REED, Edgar Howard (Junior, 1905), Supt., Reed & Prince Mfg. Co., Duncan Ave., and *for mail,* Wildwood Ave., Worcester, Mass.

ROSS, Charles Everett (1900), Cons. Engr., 52 Beaver St., and *for mail,* Hotel Chelsea, W. 23d St., New York, N. Y.

SHALLENBERGER, Louis R. (1895; 1902), Civ. and Mech. Engr., Paonia, Colo.

STREET, Clement F. (1893), with firm of Clement F. Street, Locomotive Stokers, 166 Washington Ave., and *for mail*, P. O. Box 192, Schenectady, N. Y.

STRUCKMANN, Holger (1909), Ch. Engr. and Genl. Mgr., Iola Portland Cement Co., Iola, Kan.

THOMAS, James Winthrop (1905), Mech. Engr., New England Engrg. Co., 50 Church St., New York, N. Y.

TRUELL, Karl O. (Associate, 1906), Colloseus Cement Co., 26 Beaver St., New York, N. Y.

TUTTLE, Irving E. (Junior, 1909), Mech. Draftsman, Westinghouse, Church, Kerr & Co., New York, and *for mail*, 475 Washington Ave., Brooklyn, N. Y.

WEGG, David S., Jr. (Junior, 1909), Telluride Inst., Olmstead, Provo, Utah, and *for mail* (temporarily), 16 E. Ontario St., Chicago, Ill.

WILDER, Clifton W. (1907), Elec. Engr., Pub. Service Com., 154 Nassau St., New York, N. Y.

WOOLSON, Ira H. (1896), Cons. Engr., Natl. Bd. of Fire Underwriters, 135 William St., New York, N. Y.

ZIMMERMANN, John Edward (Junior, 1907), Member of Firm, Dodge, Day & Zimmermann, Engrs., Wash. Bldg., 608 Chestnut St., Philadelphia, and Willow Grove, Pa.

NEW MEMBERS

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LUNDGREN, Charles G. (1910), M. M., National Tube Co., and *for mail*, 1018 W. 8th St., Lorain, O.

DEATHS

CRUIKSHANK, Barton, June 27, 1910
GARBETT, Joseph, August 22, 1910
PORTER, Charles T., August 28, 1910
SPIES, Albert, August 16, 1910

GAS POWER SECTION

CHANGES OF ADDRESS

ADAMS, Edward T. (1909), Mem.Am.Soc.M.E.
AUE, Jos. E. (1908), Mem.Am.Soc.M.E.
MILLER, Frank Louis (1910), Mem.Am.Soc.M.E.

STUDENT BRANCHES

CHANGES OF ADDRESS

ALLEN, Chas. L. (Student, 1910), Waterford, New York.
BOHNSTENGEL, Walter (Student, 1909), Dodge City, Kansas.
COLBURN, B. V. (Student, 1910), 911 Marion Ave., Cincinnati, O.
COYLE, J. F. (Student, 1909), 353 Wright St., Kingston Sta., Wilkes Barre, Pa.
FEHR, Roy B. (Student, 1910), 618 Kelly St., Wilkinsburg, Pa.
HELLER, Alfred (Student, 1909), Lackawanna Club, Lackawanna, N. Y.
HILFORD, V. H. (Student, 1909), Box 488, Caney, Kansas.
HODGSON, J. H. S. (Student, 1910), 89 Douglas St., Hammond, Ind.
JACOBSEN, C. H. (Student, 1910), 432 64th Ave., West Allis, Wis.
JAHNKE, Chas. B. (Student, 1910), care Mr. Northrop, Church St., Beloit, Wis.
JANDA, Jas. F. (Student, 1909), Y. M. C. A. Bldg., Aurora, Ill.
KERR, George W. (Student, 1910), 618 Kelly St., Wilkinsburg, Pa.
KONSTANKEWICZ, M. J. (Student, 1910), 116 W. 5th Ave., Gary, Ind.
LEHMAN, Myron G. (Student, 1910), 228 Elmwood Ave., Buffalo, N. Y.
LEVY, M. S. (Student, 1909), care Mrs. E. Stoefler, Amer. Shoe Store, 2 Rue du Quatre, Paris, France.
LOHSE, A. W. (Student, 1909), 3249 S. Park Ave., Chicago, Ill.
MANSFIELD, W. M. (Student, 1909), 312 Ferdinand Ave., Detroit, Mich.
MATTHAI, A. D. (Student, 1910), 1 Monroe Pl., Brooklyn, N. Y.
MERRIAM, Frank E. (Student, 1910), 815 South Ave., Wilkinsburg, Pa.
MOBLEY, Roy H. (Student, 1910), 1933 Market St., Philadelphia, Pa.
MONTGOMERY, Stafford (Student, 1910), Strafford, Chester Co., Pa.
NIXDORFF, S. P. (Student, 1909), 773 State St., Schenectady, N. Y.
PHILLIPS, Ernest C. (Student, 1910), Box 712, Gary, Ind.
POLHEMUS, D. A. (Student, 1910), 1106 Carnegie Bldg., Pittsburg, Pa.
PRIESTER, HENRY (Student, 1909), 21 Essex St., Hackensack, N. J.
REYNOLDS, Herbert B. (Student, 1909), 106 Highland Pl., Ithaca, N. Y.
SCHLEGEL, Carl A. (Student, 1910), 1005 University Ave., S. E., Minneapolis, Minn.
SCHULTZ, A. F. (Student, 1910), 1118 Franklin Ave., Wilkinsburg, Pa.
SMITH, Temple C. (Student, 1910), 38 Fulton St., Newark, N. J.
STEED, Arthur (Student, 1910), 824 Rebecca St., Wilkinsburg, Pa.
TRANE, R. N. (Student, 1910), 106 Lincoln Ave., Milwaukee, Wis.
WERNICK, F. E. (Student, 1909), 1110 13th St., Moline, Ill.
WHEDBEE, Edgar (Student, 1909), 190 S. Oxford St., Brooklyn, N. Y.
WOODS, Arthur P. (Student, 1909), Turtle Creek, Pa.
YOUNG, D. A. (Student, 1909), Delagua, Colo.

COMING MEETINGS

October—November

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 21-23, annual convention, Anniston, Ala. Secy., Geo. S. Emery.

AMERICAN ELECTROCHEMICAL SOCIETY
October 13-15, annual meeting, Chicago, Ill. Secy., Jos. W. Richards, Lehigh University, Bethlehem, Pa.

AMERICAN INSTITUTE OF MINING ENGINEERS
October 21-November 15, special meeting, Canal Zone, S. A. Secy., Dr. Joseph Struthers, 29 W. 39th St., New York.

AMERICAN MINING CONGRESS
September 26-October 1, annual convention, Los Angeles, Cal. Managing director, Sidney Norman.

AMERICAN RAILWAY ASSOCIATION
November 16, semi-annual meeting, St. Louis, Mo. Secy., W. F. Allen, 24 Park Pl., New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS
October 5, 19, 220 W. 57th St., New York. Papers: October 5, Tieton Canal, E. G. Hopson; October 19, The Reconstruction of the Passenger Terminals at Washington, D. C., W. F. Strouse. Secy., C. W. Hunt.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENT
October 11-16, annual convention, Erie, Pa. Secy., Prescott Folwell, 239 W. 39th St., N. Y.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION
October 10-14, annual convention, Atlantic City, N. J. Secy., H. C. Donecker, 29 W. 39th St., New York.

AMERICAN RAILWAY BRIDGE AND BUILDING ASSOCIATION
Oct. 18-20, annual convention, Fort Worth, Ind. Secy., C. A. Lichty, 215 Jackson Blvd., Chicago, Ill.

ILLUMINATING ENGINEERING SOCIETY
October 24, annual convention, Baltimore, Md. Secy., P. S. Millar, 29 W. 39th St., New York.

INTERNATIONAL CONGRESS OF REFRIGERATION
October 9-12, University of Vienna, Austria. Papers: Constructing and Testing Refrigeration Machinery and Insulating Materials, Application of Refrigeration to Food, Industrial Refrigeration, Railway and Steam-

ship Refrigeration, Legislation and Administration. Chairman of Committee on Transportation, F. W. Pilsbury, 1660 Monadnock Block, Chicago, Ill.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS

November 16-23, annual meeting, Washington, D. C. Reports: Powers, Duties and Work of State Railway Commissions, Legislation, Shippers' Claims on Common Carriers, Railway Service and Railway Accommodation, Construction and Operating Expenses of Electric Railways, Simplification of Railway Tariffs, Rates and Rate Making, Uniform Classification, Car Service and Demurrage, Railway Capitalization, Safety Appliances, Grade Crossings and Trespassing on Railroads, Railroad Taxes and Plans for Ascertaining the Fair Value of Railroad Property, Amendment of Act to Regulate Commerce, Delays Attendant upon Enforcing Orders of State Railway Commissions. Secy., Wm. H. Connolly, c/o Interstate Commerce Commission.

NATIONAL MUNICIPAL LEAGUE

November 14-18, annual meeting, Buffalo, N. Y. Secy., Clinton Rogers Woodruff, North American Bldg., Philadelphia, Pa.

RAILWAY SIGNAL ASSOCIATION

October 11-13, annual meeting, Richmond, Va. Secy., C. C. Rosenberg, Bethlehem, Pa.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time p.m.
October			
5	Wireless Institute	S. L. Williams	7.30
5	Empire State Gas and Electrical Association	C. H. B. Chapin	All day
6	Blue Room Engineering Society	W. D. Sprague	8.00
11	American Society of Mechanical Engineers	C. W. Rice	8.15
13	Illuminating Engineering Society	P. S. Millar	8.15
14	American Institute of Electrical Engineers	R. W. Pope	8.00
18	New York Telephone Society	T. H. Lawrence	8.00
19, 20, 21	American Gas Institute	A. B. Beadle	All day
21	New York Railroad Club	H. D. Vought	8.15
26	Municipal Engineers of New York	C. D. Pollock	8.15
November			
2	Wireless Institute	S. L. Williams	7.30
3	Blue Room Engineering Society	W. D. Sprague	8.00
8	American Society Mechanical Engineers	C. W. Rice	8.15
10	Illuminating Engineering Society	P. S. Millar	8.15
11	American Institute of Electrical Engineers	R. W. Pope	8.00
15	New York Telephone Society	T. H. Lawrence	8.00
17–18	Society of Naval Architects and Marine Engineers	W. J. Baxter	All day
18	New York Railroad Club	H. D. Vought	8.15
23	Municipal Engineers of New York	C. D. Pollock	8.15

CURRENT BOOKS

THE RAILWAY LIBRARY 1909. A Collection of Noteworthy Chapters, Addresses and Papers Relating to Railways, Mostly Published during the Year. Compiled and Edited by Slason Thompson. *Chicago, The Gunthorp-Warren Printing Co., 1910.* Cloth, 8vo, 403 pp.

Contents: Introduction; Pre-Railway Era in America, by F. A. Cleveland and F. W. Powell; First Annual Report of the Chief Engineer of the Pennsylvania Railroad Company, by J. Edgar Thompson; Railways and the Pacific Northwest, by James J. Hill; Southern Railways and their Needs, by John F. Wallace; Problems confronting American Railways, by Daniel Willard; The Railroad Situation of To-day, by Frank Trumbull; Transportation Charge and Prices, by Logan G. McPherson; The Freight Rate Primer, issued by the N. Y. C. & H. R.R.R. Co.; Progressive Safety in Railway Operation, by A. H. Smith; Railway Mail Pay, by Julius Kruttschnitt; The Diminished Purchasing Power of Railway Earnings, by C. C. McCain; The Railroads and Public Approval, by Edward P. Ripley; Railroads and the Public, by John C. Spooner; Railroad Problems of Today, by J. B. Thayer; The Relation of the Railroads to the State, by W. M. Acworth; Railway Nationalization, by Sir George S. Gibb; Concerning Advances in Railway Rates, by the Senate Committee on Interstate Commerce, 1909; Statistics of American Railways for 1909, by Slason Thompson.

HIGH-SPEED STEEL. The Development, Nature, Treatment and Use of High-Speed Steels, together with some Suggestions as to the Problems involved in their Use. By O. M. Becker. *New York, McGraw-Hill Book Co., 1910.* Cloth, 8vo, 360 pp., Price, $4 net.

Contents: Introduction; Section I. The Development and Nature of High-Speed Steels; Section II. Making the Steels and the Tools; Section III. The Tool at Work; Section IV. The New Requirements; Section V. Problems Involved in the Use of High-Speed Steels; Section VI. Appendices.

FACTORY ORGANIZATION AND ADMINISTRATION. By Hugo Diemer. *New York, McGraw-Hill Book Co., 1910.* Cloth, 8vo, 317 pp., Price, $3 net.

Contents: Industrial Engineering; The Economic Theory of Factory Location; The Planning of Factory Buildings and the Influence of Design on their Productive Capacity; Staff and Departmental Organization;Executive Control in the Factory; Departmental Reports; The General Office; The Order Department; Bills of Material; The Drafting Department; The Pattern Department; Stores and Stock Departments; The Production Department; Foundry Systems; The Machine Shop and Tool Department; Shipping and Receiving Departments; Time Taking; Cost Department; Aids in Taking Inventory; Inspection Methods in Modern Machine Shops; Employment of Labor and Labor Problems; Wage Systems; The Fixing of Piece Work Rates; Principles Underlying Good Management; A Bibliography of Works Management.

COMPRESSED AIR. Theory and Computations. By Elmo G. Harris. *New York, McGraw-Hill Book Co., 1910.* Cloth, 8vo, 123 pp., Price $1.50.

Contents: Formulas for Work; Measurement of Air; Friction in Air Pipes; Hydraulic and Centrifugal Air Compressors; Special Applications of Compressed Air; The Air-Lift Pump; Examples and Exercises; Plates and Tables; Appendices.

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On Society History

John E. Sweet
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On Constitution and By-Laws

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	1909			
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Leland Stanford Jr. University, Palo Alto, Cal.	March 9	W. F. Durand	A. F. Meston	J. B. Bubb
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State Agri. College, Corvallis, Ore.	March 9	Thos. M. Gardner	C. L. Knopf	S. H. Graf
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University of Kansas, Lawrence, Kan.	March 9	P. F. Walker	C. E. Johnson	C. A. Swiggett
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Univ. of Cincinnati, Cincinnati, O.	November 9	J. T. Faig	H. B. Cook	C. J. Malone
Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	John S. Langwill	Karl L. Kraatz
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	W. J. Wohlenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams

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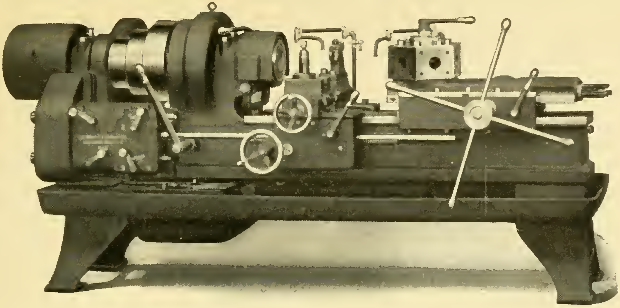

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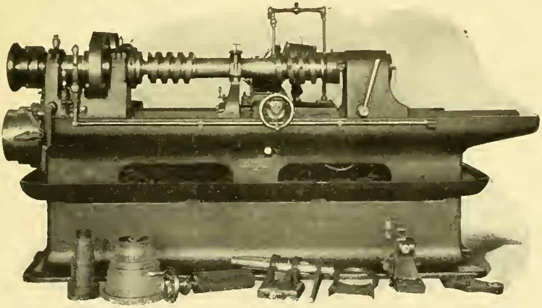

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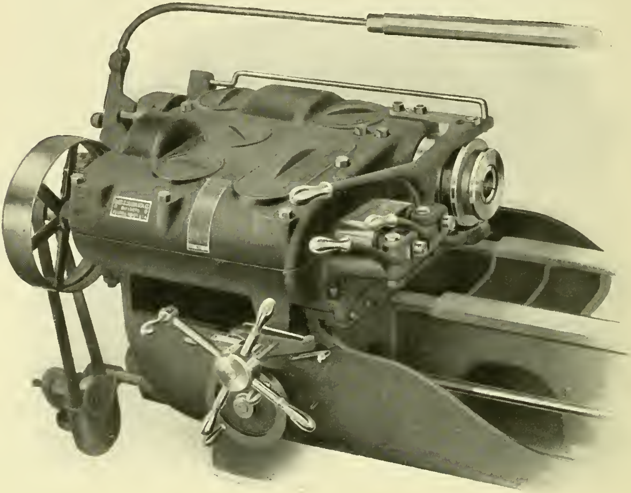

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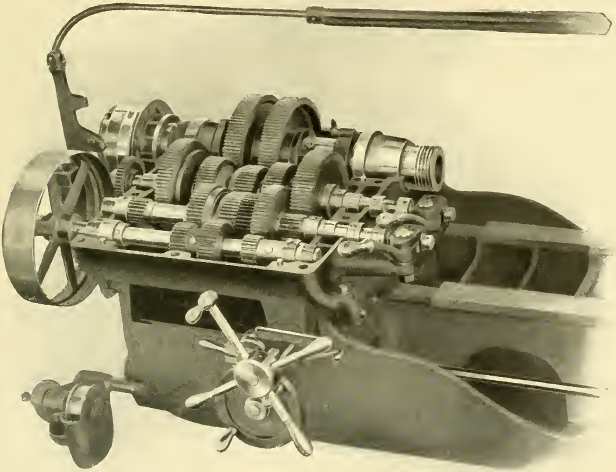

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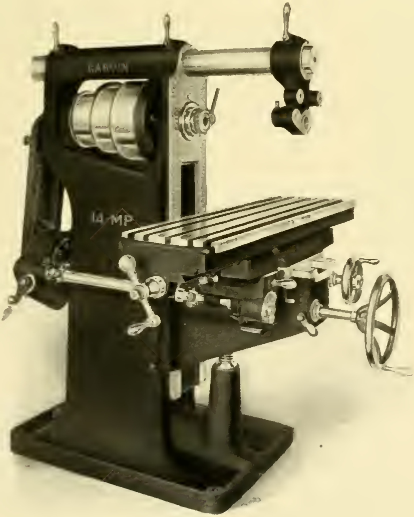

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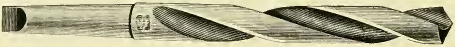

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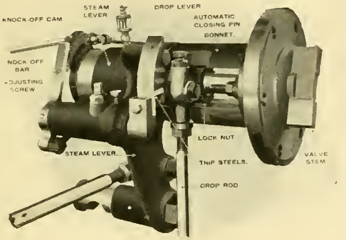

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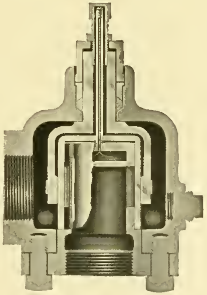

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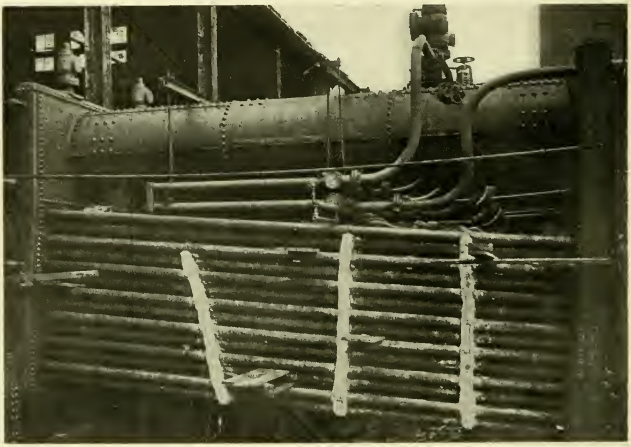

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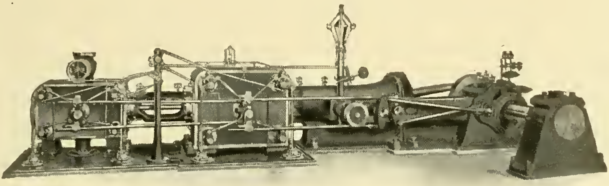

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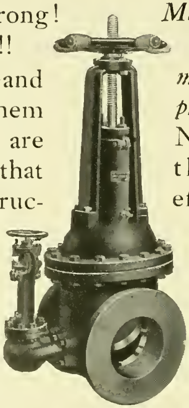

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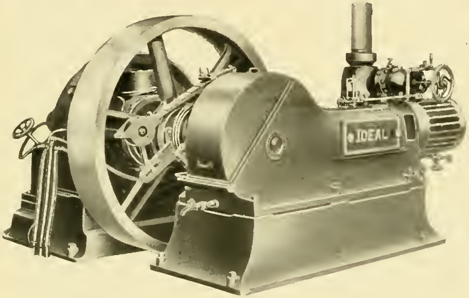

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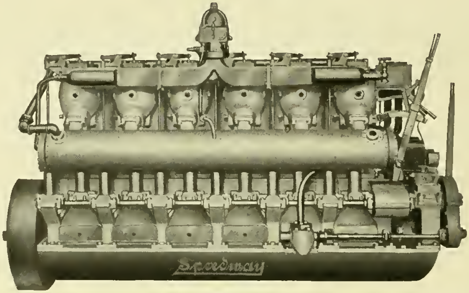

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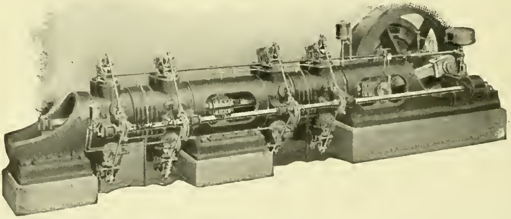

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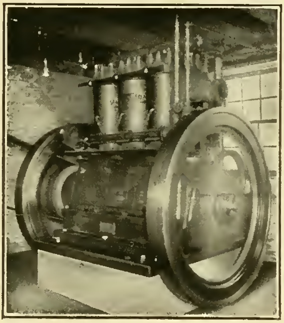

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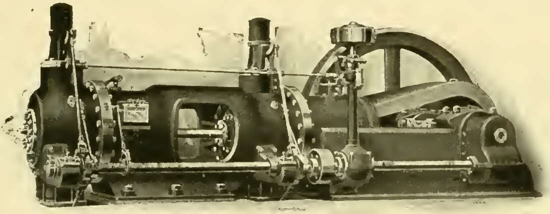

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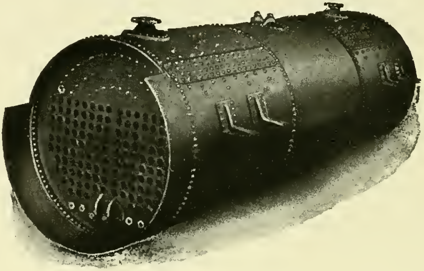

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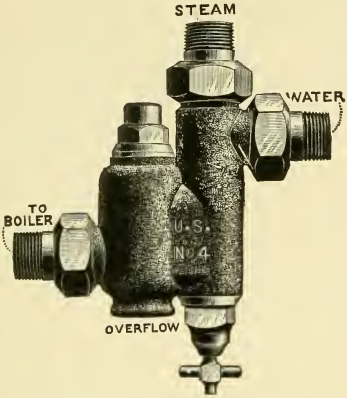

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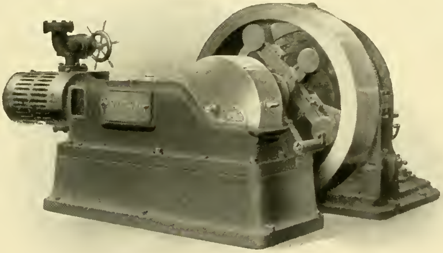

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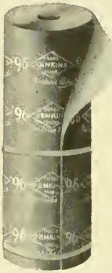

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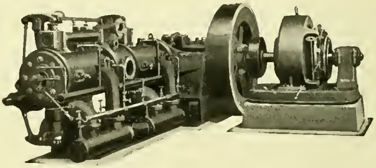

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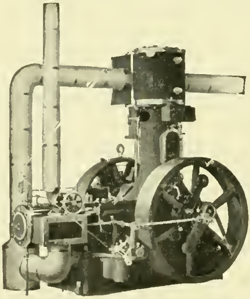

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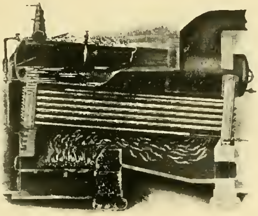

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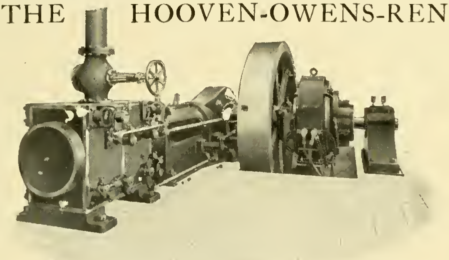

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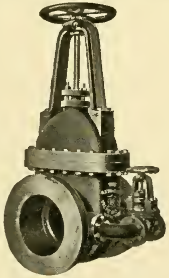

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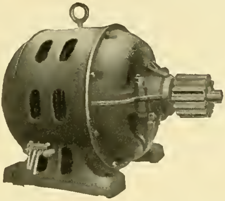

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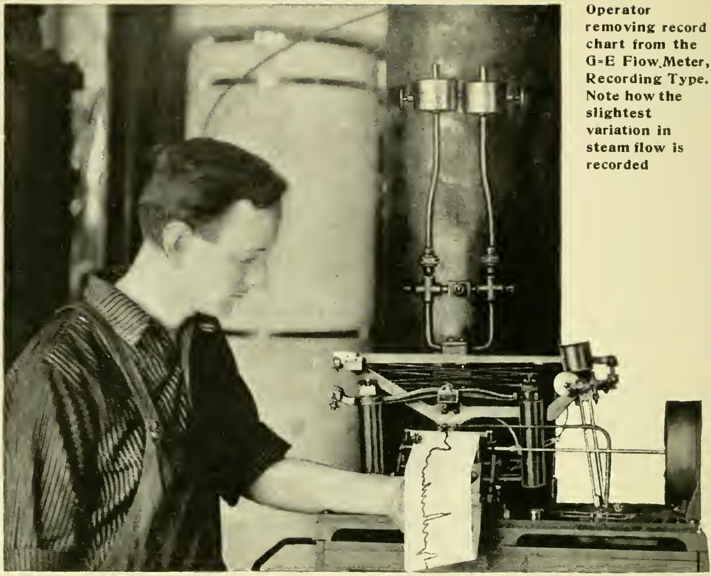

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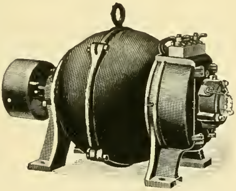

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25–1010	Slide Rules for the Machine Shop, C. G. Barth	20
27–1115	History of a System of Shop Management, J. M. Dodge	.10
		$4.70

$4.00 for the set.

Members' rates are half the list price.

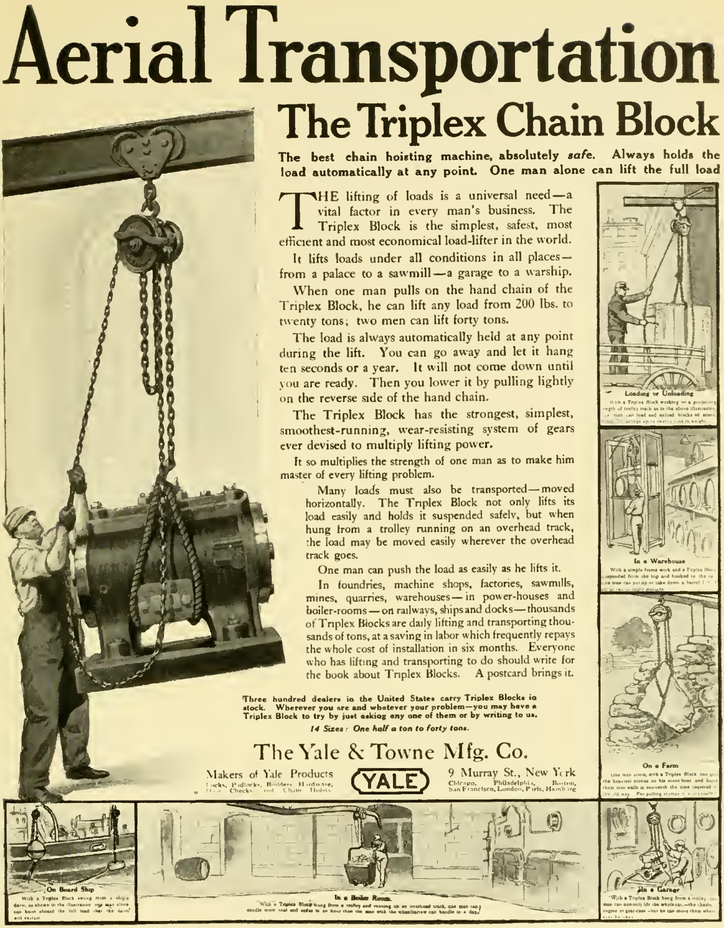
Address Calvin W. Rice, Secretary, 29 West 39th St., New York

ADVERTISING SUPPLEMENT

SECTION 4

Hoisting and Conveying Machinery
Power Transmission

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
Directory of Mechanical Equipment - - - Section 6



Aerial Transportation

The Triplex Chain Block

The best chain hoisting machine, absolutely *safe*. Always holds the load automatically at any point. One man alone can lift the full load

THE lifting of loads is a universal need—a vital factor in every man's business. The Triplex Block is the simplest, safest, most efficient and most economical load-lifter in the world.

It lifts loads under all conditions in all places—from a palace to a sawmill—a garage to a warship.

When one man pulls on the hand chain of the Triplex Block, he can lift any load from 200 lbs. to twenty tons; two men can lift forty tons.

The load is always automatically held at any point during the lift. You can go away and let it hang ten seconds or a year. It will not come down until you are ready. Then you lower it by pulling lightly on the reverse side of the hand chain.

The Triplex Block has the strongest, simplest, smoothest-running, wear-resisting system of gears ever devised to multiply lifting power.

It so multiplies the strength of one man as to make him master of every lifting problem.

Many loads must also be transported—moved horizontally. The Triplex Block not only lifts its load easily and holds it suspended safely, but when hung from a trolley running on an overhead track, the load may be moved easily wherever the overhead track goes.

One man can push the load as easily as he lifts it.

In foundries, machine shops, factories, sawmills, mines, quarries, warehouses—in power-houses and boiler-rooms—on railways, ships and docks—thousands of Triplex Blocks are daily lifting and transporting thousands of tons, at a saving in labor which frequently repays the whole cost of installation in six months. Everyone who has lifting and transporting to do should write for the book about Triplex Blocks. A postcard brings it.

Three hundred dealers in the United States carry Triplex Blocks in stock. Wherever you are and whatever your problem—you may have a Triplex Block to try by just asking any one of them or by writing to us.

14 Sizes: One half a ton to forty tons.

The Yale & Towne Mfg. Co.

Makers of Yale Products
Locks, Padlocks, Builders' Hardware, Door Checks and Chain Hoists

YALE

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Chicago, Philadelphia, Boston, San Francisco, London, Paris, Hamburg

Loading or Unloading

With a Triplex Block working on a projecting length of trolley track as in the above illustration, one man can load and unload blocks of stone, [illegible] swings up to twenty tons in weight

In a Warehouse

With a simple frame work and a Triplex Block suspended from the top and hooked to the ca one man can put up or take down a barrel [illegible] in two or three minutes.

On a Farm

One man alone, with a Triplex Block can p the heaviest stones on his stone-boat and build them into walls in one-tenth the time required in the old way. For pulling stumps it is unequalled.

On Board Ship

With a Triplex Block swung from a ship's davit, as shown in the illustration, one man alone can hoist aboard the full load that the davit will sustain.

In a Boiler Room

With a Triplex Block hung from a trolley and running on an overhead track, one man can handle more coal and ashes in an hour than the man with the wheelbarrow can handle in a day.

In a Garage

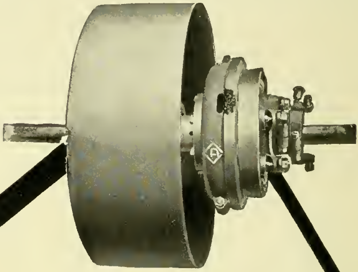
With a Triplex Block hung from a trolley, one man can not only lift the whole car,—the chassis, engine or gear-case—but he can move them wherever he likes.

The Triplex Block would prove itself a real necessity in thousands of places where it is not even known today.

This is why we spent $3,000 to print the above full-page advertisement in the Saturday Evening Post of Sept. 17th.

DODGE

Here's A Clutch That "Makes Good"



THE Summit Thread Co., East Hampton, Conn., who use the Dodge Split Friction Clutch, recently wrote us—"We have been using one of your clutches for about three years, and while our experience with friction clutches in general has been rather unsatisfactory, the clutch of your make has never caused any trouble whatever." ◈ The Dodge Split Friction Clutch is a real service-giver. It is doing the hardest kind of work in rolling mills, cement mills, rubber mills, mines and smelters and other industries. Some of the largest concerns in these lines have adopted our clutch as their standard, after exhaustive trials and tests of clutches of different makes. ◈ Dodge Clutches are dependable power-savers. Each department, each lineshaft, even each machine throughout your plant may be controlled independently of all the balance of the equipment. Consider the immense saving in power by shutting down idle machines, by having the equipment under instant control in one case of accident to men or machinery.

◈ We will be glad to advise with you about Dodge Friction Clutches to exactly meet your requirements. Write us about your possible clutch needs. ◈ Your name on the coupon brings our Clutch Bulletin J-116, which tells about this "economy mechanism." Have us send this book to you at once.

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STATION J-45, MISHAWAKA, INDIANA

"Everything for the Mechanical Transmission of Power"

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St. Louis Brooklyn Atlanta Cincinnati
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Dodge Manufacturing Company, Mishawaka, Ind.
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Please send me your Bulletin J-116
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Town..........
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THE
McCASLIN
CONVEYOR

Mead-Morrison
Manufacturing Company

NEW YORK BOSTON CHICAGO

THE *McCaslin Noiseless Overlapping Gravity Bucket Conveyor* is the superior of any similar device offered to-day for the conveying of Coal, Ashes, Hot Clinker, etc., in Power Stations or Cement Mill Service. *Correspondence invited.*

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STANDARD
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Economical Methods of Handling Materials

We design and build Conveyors in styles and capacities suitable for whatever materials they are to handle and whatever conditions they are to operate under.

Give us an opportunity to figure on your conveying requirements and write for our Catalog K 81, illustrating systems in operation.

THE JEFFREY MFG. CO.
COLUMBUS, OHIO

Conveyor Belt User

Have you had trouble with the Edge of Your Belt? Does it come loose, peel, break off, or wear away? Then let your next belt be a

Goodrich Conveyor Belt

Edge Construction—Goodrich Conveyor Belt

This is the best edge ever put on a conveyor belt. Notice how the top cover is carried around into the back cover without leaving a thin corner to break loose. No square corners to catch. No molded edge to peel off. The edge is formed by a special process of our own and is vulcanized before the rest of the belt so that the adhesion of the corner around the edge is as perfect as elsewhere. This edge cover stays on until worn off and thus protects the fabric from the entrance of moisture which quickly deteriorates the whole belt and causes the thick top cover to peel off. *We make a good belt with a real edge.*

The B. F. Goodrich Company
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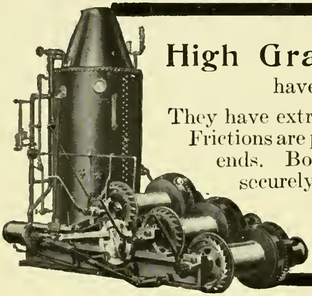
NOT IN THE TRUST

ELEVATORS

EVERY TYPE



CLYDE

High Grade Hoisting Engines

have steel gears and ratchets.

They have extra heavy shafting and long bearings. Frictions are positive. Connecting rods have solid ends. Boilers have large heating capacity and securely anchored. *Ask for Catalogue.*

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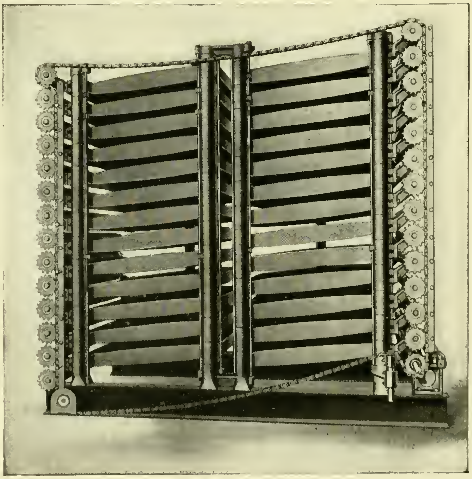
DIAMOND CHAIN REPLACES GEARING HERE



The cell driers made by Cell Drier Machine Co., Taunton, Mass., have anywhere from 6 to 40 trays and rolls each. Formerly the rolls were driven by gearing but this consumed too much power. The trains of gears have been supplanted by a single loop of Diamond roller chain.

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Capacity 8,000,000 ft. per year (74)

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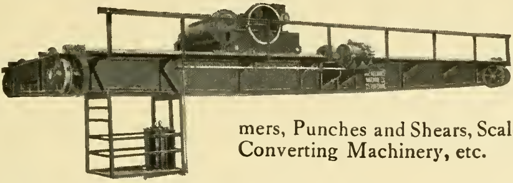

Also Rolling Mill and Hydraulic Machinery, Steam Hammers, Punches and Shears, Scale Cars, Copper Converting Machinery, etc.

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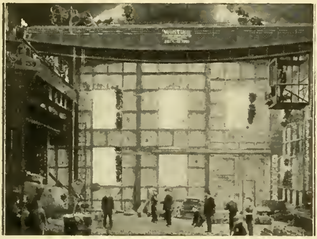

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Buildings designed and furnished. Equipment installed and operated. Plant delivered to purchasers ready to run.

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No 3, 1882
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No. 7, 1886
No. 12, 1891, July
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No. 14, 1893, January
No. 14, 1893, July

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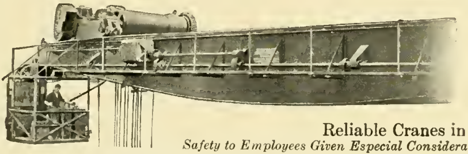
We send bulletins describing same on request.

You get the most Reliable Cranes in the "NORTHERN."



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VOL. 30

The American Society of Mechanical Engineers

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- Hoisting and Conveying Machinery.
- Continuous Conveying of Materials.
- The Belt Conveyor.
- Conveying Machinery in a Cement Plant.
- Performance of Belt Conveyors

PROPERTIES OF STEAM

- Thermal Properties of Superheated Steam.
- A Method of Obtaining Ratios of Specific Heat of Vapors.
- The Total Heat of Saturated Steam.

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- Efficiency Tests of Milling Machines and Milling Cutters.
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- Horse Power, Friction Losses and Efficiency of Gas and Oil Engines.
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29 West 39th Street, New York

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SECTION 5

Engineering Miscellany

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
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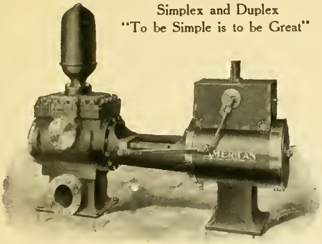
Simplex and Duplex
"To be Simple is to be Great"



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are ideal for intermittent service. They cannot short stroke, race or pound and can be adjusted to suit conditions. We guarantee very low steam consumption and minimum cost for repairs.

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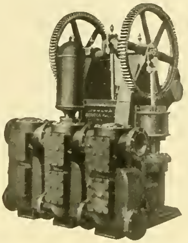
Branches in all large cities



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Of all Descriptions

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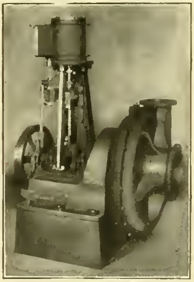

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AN ACCURATE DEVICE FOR MEASURING HOT WATER

The complete Venturi Meter, consists of two parts, the Meter-tube and the Indicator-Recorder. The Meter-tube, the only part of the Meter coming in contact with the hot water, contains absolutely no mechanism of any kind. It is really part of the pipe line, and cannot be injured by water hammer or the most violent fluctuations of pressure or velocity. It can be set at any convenient angle, vertically, horizontally, uphill, downhill, it makes no difference.

Brief description of the Recording Instrument in next month's advertisement.

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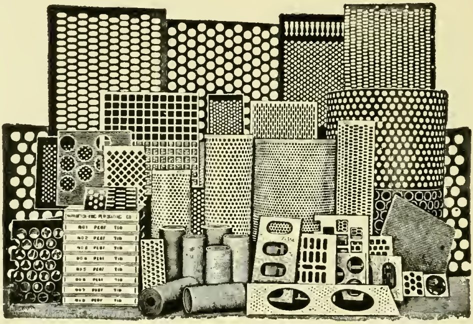

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¶ For Electrical Manufacturing, Storage Batteries, Rheostat and Controller Covers, Car Heaters, Lamps, Water Purifiers, Electric Vehicles, Automobiles and other uses.

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¶ Standard sizes of Perforated Brass and Tin only in stock. Other work is to order.

¶ Send full specifications and sample if possible, as we have as large a variety of sizes and patterns of dies as can be found anywhere.

¶ Doubtless we have just what you want or can make it, and quotations will be satisfactory.

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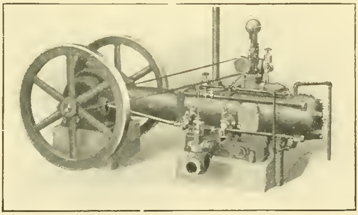
FRANKLIN AIR COMPRESSORS ARE especially designed for all classes of compressed air equipment in machine shops, boiler shops, railroad shops, ship yards and in bridge and building construction work, and for every other purpose in which compressed air is employed.



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This newest edition is just off the press with all the latest information on graphite lubrication. Big type, easy to read and worth reading. Write for free copy 199-C.

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Papers read before

The American Society of Mechanical Engineers

from 1890 to 1908

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No.		Price to Members	Non-Members
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853	Pumping Engine Test with Superheated Steam, E. H. Foster	5	10
905	The Practical Application of Superheated Steam, Geo. A. Hutchinson	15	30
906	Superheated Steam, Ernest H. Foster	5	10
1024	Tests of a Compound Engine using Superheated Steam, D. S. Jacobus	10	20
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SET COMPLETE		$2.00	4.00

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SECTION 6

DIRECTORY OF MECHANICAL EQUIPMENT

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DERBY LINE, VT. ROCK ISLAND, P. Q.

Manufacturers of Taps, Dies, Screw Plates, Stocks and Dies, Tap Wrenches, and all Thread Cutting Tools. Our goods are not surpassed by any in the world.

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NIAGARA FALLS, N. Y.

Sole manufacturers in America of Carborundum, the hardest, sharpest, quickest cutting and most uniformly perfect abrasive material known. The Carborundum products include: Grinding Wheels for every possible grinding need, Sharpening Stones, Oil Stones, Rubbing Bricks, Carborundum Paper and Cloth, Valve Grinding Compound, Carborundum Grains and Powders, and Garnet Paper.

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MANSFIELD, MASS., U. S. A.

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PAWTUCKET, R. I.

Carpenter's Tools for cutting Screw Threads, Taps, Dies, Screw Plates, Dies and Stocks, Tap Wrenches, etc., have been 38 years on the market and 38 years in the lead.

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CINCINNATI GEAR CUTTING MACHINE CO.

CINCINNATI, O.

Our Automatic Spur Gear Cutting Machines exceed in power and capacity and equal in accuracy any machines of their type made.

GEAR CUTTING MACHINES

THE CINCINNATI SHAPER CO.

CINCINNATI, O.

We manufacture the most complete line of Shapers made, including Plain Crank, Back Geared Crank, Geared Rack, Open Side and Traverse Shapers, as well as Crank Planers.

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THE FELLOWS GEAR SHAPER CO.

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The Gear Shaper cuts the smoothest gears in use, because the cutter is a theoretically correct generating tool and is ground after being hardened. It is also the fastest machine on the market by 25 to 50%. Literature gives reasons in detail.

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MILLING MACHINES

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Manufacturers of a complete line of Plain and Universal Milling Machines, Screw Machines, Monitor Lathes, Tapping Machines, Duplex Drill Lathes, Speed Lathes, Cutter Grinders, Automatic Chucks, etc.

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SEPTEMBER 1910

ALPHABETICAL LIST OF ADVERTISERS

Page
Alliance Machine Co 29, 49
Allis-Chalmers Co...9, 21, 42, 52, 53
Almy Water Tube Boiler Co...... 40
American Engine Co..........16, 40
American Injector Co.........15, 43
American Pulley Co.............. 48
American Steam Gauge & Valve Mfg. Co...................... 43
American Steam Pump Co.....31, 52
Arnold Co., The................. 35
Ashton Valve Co................ 43
Atlantic Hydraulic Machinery Co. 52

Babcock & Wilcox Co.........16, 40
Baldwin, Bert. L................ 35
Ball Engine Co.............. ... 40
Blaisdell Machinery Co.......... 54
Bridgeport Brass Co............. 44
Bristol Co...................... 44
Broderick & Bascom Rope Co.... 49
Brown Hoisting Mchy. Co...... 49
Bruce-Macbeth Engine Co...... 42
Buckeye Engine Co..........12, 40
Builders Iron Foundry........31, 52
Bulkley, Henry W.............. 44
Butterfield & Co................ 37

Caldwell & Son Co., H. W....... 49
Carborundum Co................ 37
Card Mfg. Co., S. W............ 37
Carpenter Tap & Die Co., J. M..5, 37
Chapman Valve Mfg. Co.... 44
Chicago Pneumatic Tool Co..33, 54
Cincinnati Gear Cutting Machine Co............................ 37
Cincinnati Shaper Co............ 37
Clarkson School of Technology... 35
Clyde Iron Works...........28, 50
Conard, William R............ 35
Crosby Steam Gage & Valve Co.. 44

Dallett Co., Thos H............ 54
Davidson Co., M. T............. 52
Dean, F. W..................... 35
Dearborn Drug & Chemical Wks. 44
De La Vergne Mach. Co........ 42
Diamond Chain & Mfg. Co...28, 48
Dixon Crucible Co., Joseph..34, 44
Dodge, Day & Zimmermann...55, 56
Dodge Mfg. Co.............24, 48

Page
Dodge Co., J. M............... 50
Du Bois Iron Works..........16, 42

Eastern Machinery Co.......... 50
Engineering Schools & Colleges.. 35
Erie City Iron Works............ 40
Exeter Machine Works.......... 47

Fellows Gear Shaper Co......... 37
Franklin Boiler Works Co....17, 40

Garvin Machine Co...........5, 38
Gas Engine & Power Co., and Chas. L. Seabury & Co., Cons.12, 43
General Electric Co..........20, 53
Goodrich Co., B. F...........27, 50
Goulds Mfg. Co..............31, 52
Goyne Steam Pump Co.......... 53
Grant Mfg. & Machine Co...... 38

Harrington & King Perforating Co........................ 32, 55
Harrisburg Foundry & Machine Works......................... 41
Harrison Safety Boiler Works.... 44
Heine Safety Boiler Co........17, 41
Herrick, J. A.................. 35
Hewes & Phillips Iron Works...9, 41
Hill Clutch Co.................. 48
Holyoke Machine Co.......... 53
Homestead Valve Mfg. Co...... 45
Hooven, Owens, Rentschler Co.17, 41
Hoppes Mfg. Co................. 45
Hughson Steam Specialty Co.. 45

Ide & Sons, A. L............11, 41

Jakobsson, Herman.............. 35
Jeffrey Mfg. Co..............27, 50
Jenkins Bros.................16, 45
Jones & Lamson Machine Co. 2, 3, 38

Keasbey Co., Robt. A............. 45
Kennedy Valve Mfg. Co......17, 45
King Machine Tool Co.......... 38

Laclede-Christy Clay Products Co.............................. 45
Le Blond Machine Tool Co., R. K.. 38

Page

Lidgerwood Mfg. Co.......... 50
Link-Belt Co.......... 50
Ludlow Valve Mfg. Co.......... 45

McCord & Co.......... 46
Main, Chas. T.......... 35
Manning, Maxwell & Moore.... 6, 38
Mead-Morrison Mfg. Co......25, 50
Mietz Iron Foundry & Machine Works, August.......... 43
Monarch Valve & Mfg. Co.......... 46
Morehead Mfg. Co.......... 46
Morgan Engineering Co.......... 51
Morris Machine Works........31, 53
Murray Iron Works Co........14, 41

National Brake & Clutch Co..... 49
National Machine Co.......... 38
National Machinery Co......6, 38
National Meter Co..........13, 43
Nelson Valve Co..........10, 46
New Process Raw Hide Co... 4, 39
New York University School of Applied Science.......... 35
Nicholson & Co., W. H.......... 46
Niles-Bement-Pond Co.......... 39
Northern Engineering Works..29, 51

Ohio Injector Co.......... 46
Oneida Steel Pulley Co.......... 48
Otis Elevator Co..........26, 51

Paxson Co., J. W.......... 55
Peterson, J. Wm.......... 35
Polytechnic Institute of Brooklyn 35
Power Plant Specialty Co.......... 46
Power Specialty Co..........8, 46
Pratt & Whitney Co.......... 1
Professional Cards.......... 35
Providence Engineering Works.. 41

Quimby, Wm. E.......... 53

Page

Reedy Co., H. J..........28, 51
Reliance Electric & Engrg. Co.... 54
Rensselaer Polytechnic Institute. 35
Ridgway Dynamo & Engine Co. 15, 41
Robb-Mumford Boiler Co....14, 42
Rockwood Manufacturing Co.... 49
Roebling's Sons Co., John A..26, 51
Roots Co., P. H. & F. M.......... 47
Ruggles-Coles Engineering Co.. 48
Russell, Burdsall & Ward Bolt and Nut Co..........6, 39

Scaife & Sons Co., Wm. B.......... 47
Shaw Electric Crane Co.......... 51
Simmons Co., John..........7, 47
Sprague Electric Co..........21, 54
Standard Roller Bearing Co...34, 55
Standard Tool Co.......... 6, 39
Stephens-Adamson Mfg. Co.......... 51
Struthers-Wells Co..........13, 43
Sturtevant Co., B. F.......... 48

Tight Joint Co.......... 47
Tufts College.......... 35

Wagner Electric Mfg. Co.......... 54
Waltham Machine Works.......... 39
Warner & Swasey Co..........1, 39
Webster Mfg. Co.......... 51
Westinghouse Electric & Mfg. Co..........19. 54
Westinghouse Machine Co....19, 42
Wheeler Condenser & Engrg. Co.. 47
Wheeler Mfg. Co., C. H.......... 47
Whiting Foundry Equipment Co. 29, 55
Wiley & Russell Mfg Co.......... 39
Wisconsin Engine Co..........7, 42
Wood's Sons Co., T. B.......... 49

Yale & Towne Mfg. Co.... ...23, 52

v1
LIBRARY

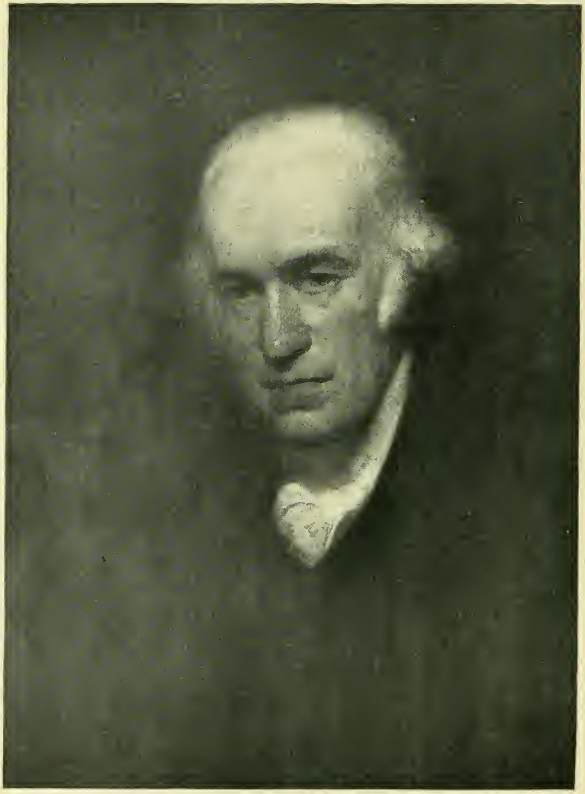
THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

NOVEMBER 1910

MEETINGS OF THE SOCIETY: NEW YORK, NOVEMBER 9;
BOSTON, NOVEMBER 10; ST. LOUIS, NOVEMBER 12;
ANNUAL MEETING, NEW YORK, DECEMBER 6-9



JAMES WATT

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NOVEMBER 1910 VOL. 32 No. 11

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CONTENTS

SOCIETY AFFAIRS

Monthly Meetings: New York, November (3); Boston, November (3); St. Louis, November (4). Annual Meeting (4). Reports of Meetings: New York, October (5); San Francisco, October (6); St. Louis, October (7); Boston, October (7). John Fritz Medal Award (7). Charles T. Porter (8). Tribute to Dr. Raymond (9). Student Branches (10). Meeting of the Council (12). Necrology (15).

PAPERS

The Joint Meeting in England, Calvin W. Rice.................... 1695
Transmission of Heat in Surface Condensation, George A. Orrok... 1771
First Large Gas-Engine Installation in American Steel Works, E. P. Coleman.................... 1835
GENERAL NOTES.................... 1927
PERSONALS.................... 1932
ACCESSIONS TO THE LIBRARY.................... 1934
EMPLOYMENT BULLETIN.................... 1941
CHANGES OF MEMBERSHIP.................... 1944
COMING MEETINGS.................... 1950
CURRENT BOOKS.................... 1953
OFFICERS AND COMMITTEES.................... 1955

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The professional papers contained in The Journal are published prior to the meetings at which they are to be presented, in order to afford members an opportunity to prepare any discussion which they may wish to present.

The Society as a body is not responsible for the statements of facts of opinions advanced in papers or discussions. C55

THE JOURNAL

OF

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 NOVEMBER 1910 NUMBER 11

COMING MEETINGS

MEETING IN NEW YORK, NOVEMBER 9

The regular New York meeting of the Society, which is ordinarily held on the second Tuesday of each month, will be held in November on the day following, i. e., Wednesday, November 9, since Election Day this year falls on the second Tuesday. The paper of the evening will be by Ellis Soper, Mem. Am. Soc. M. E., Detroit, Michigan, on the Rotary Kiln, published in The Journal for October, and there will be discussion by several engineers interested in the cement industry. Following this paper, Chas. Whiting Baker, Mem. Am. Soc. M.E., Editor of Engineering News, who was a member of the engineering commission which went to Panama with President Taft in 1909, will give an illustrated lecture on the subject of the Panama Canal. Mr. Baker has many views of work in progress and will give the results of his personal observations during his visit to the canal zone.

MEETING IN BOSTON, NOVEMBER 10

The meeting in Boston on November 10 will be in charge of The American Society of Mechanical Engineers; the Boston Society of Civil Engineers, the Boston section of the American Institute of Electrical Engineers and the Boston Chamber of Commerce coöperating.

The meeting will be a topical discussion on Smoke Abatement in Boston, participated in by D. F. Randall, Mem. Am. Soc. M. E. and others, and will be held in the auditorium of the Edison Company, 39 Boylston Street.

MEETING IN ST. LOUIS, NOVEMBER 12

A joint meeting of the Society with the Engineers Club of St. Louis will be held in the Auditorium of the Engineers Club of St. Louis, 3815 Olive St., on November 12.

THE ANNUAL MEETING

The Annual Meeting of the Society will be held in New York December 6-9, 1910. The assignment of papers for the meeting will be made from those published in The Journal for October, November and December. The program for the meeting is in preparation and will be announced at an early date.

RAILROAD TRANSPORTATION NOTICE

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 6-9, 1910, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 2 and 8 inclusive, and get a certificate, *not a receipt,* securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager, at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 9.

d An agent of the Trunk Line Association will validate certificates, Dec. 7, 8, 9. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to Dec. 13, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:

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All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie Sarnia and Windsor, Ont.

REPORTS OF MEETINGS

MEETING IN NEW YORK, OCTOBER 11

New York monthly meetings of the Society were resumed on October 11, when a paper was presented by Frank B. Gilbreth, on Fires: Effects on Building Materials and Permanent Elimination. The meeting was held in the Engineering Societies Building with an attendance of 176.

The paper was discussed by J. P. H. Perry, of the Turner Construction Co., who emphasized the value of reinforced concrete in the construction of fireproof buildings, illustrating his remarks by a number of lantern slides. H. deB. Parsons, consulting engineer, used an interesting series of slides to show the effect of fires on tall buildings. Ira H. Woolson, of the National Board of Fire Underwriters, called attention with the aid of the lantern, to the danger of present methods of building construction, especially as applied to apartments and dwelling houses, in which little or no attempt at fireproofing is made. F. A. Waldron, industrial engineer, used a number of slides to illustrate the advantages of reinforced concrete for factory buildings. P. H. Bevier, chief engineer of the National Fire Proofing Co., discussed the use of hollow tile; Wm. D. Grier, of the National Fire Protection Association, took up numerous phases of the use of fireproof material; and written discussion was offered by E. E. Seyfert, of Pittsburg; Chas. T. Main, of Boston, and C. A. P. Turner, of Minneapolis.

MEETING IN SAN FRANCISCO, OCTOBER 14

Under the direction of the Meetings Committee, the activities of the Society are developing in a way that is truly national. Meetings are held in various cities to enable members, many of whom can seldom attend the New York meetings, to strengthen their acquaintance among engineers and to participate in the discussion of papers. During the past year meetings have been held regularly in Boston, New York and St. Louis, and during the coming year they will also be held in San Francisco and probably other cities.

The initial meeting in San Francisco was held on October 14, when members of the Society resident in San Francisco and vicinity gathered at the Palace Hotel to effect an organization. Calvin W. Rice, Secretary, went out from New York for the purpose of meeting members in San Francisco, assisting in the organization and addressing the first meeting.

The gathering was a success in every respect. The local members were enthusiastic and it is believed that much good will result to those residing on the Pacific slope as well as to other members who will be benefited indirectly through the publication, in The Journal, of material upon important engineering work in progress in that section of the country. A. M. Hunt was elected Chairman and T. W. Ransom Secretary. Prof. W. F. Durand, E. C. Jones and Thomas Morrin will constitute the Executive Committee.

A resolution was adopted inviting the Society to hold its semi-annual meeting in San Francisco during the Panama-Pacific Exposition in 1915 and the suggestion was made to the Council that an international meeting of mechanical engineering societies be held at the same time.

It is proposed to hold four local meetings in San Francisco annually.

MEETING IN ST. LOUIS, OCTOBER 15

At the meeting of the Society in St. Louis on October 15, the Engineers Club participating, the paper by Frank B. Gilbreth, on Fires: Effects on Building Materials and Permanent Elimination, was presented. W. H. Bryan presided and in the absence of the author the paper was presented by Prof. E. L. Ohle, Mem. Am. Soc. M. E., and was discussed by E. D. Meier, A. A. Aegerten, James Waterworth, Prof. H. W. Hibbard, W. H. Bryan, R. W. Maxton, G. R. Wadleigh, A. B. Greensfelder and others.

MFETING IN BOSTON, OCTOBER 19

The meeting in Boston on October 19 was conducted by the Boston Society of Civil Engineers; The American Society of Mechanical Engineers and the Boston section of the American Institute of Electrical Engineers coöperating.

Prof. Thomas A. Jaggar presented a paper on An Account of the Destruction of Carthego, Costa Rico, by Earthquake on May 4, 1910. Prof. Chas. M. Spoffard and Frank B. Gilbreth, Mem. Am. Soc. M. E., discussed the effects of earthquakes on different classes of structures with the aid of a number of views of the destruction caused by earthquakes in Carthego and elsewhere. The attendance was about 250.

THE JOHN FRITZ MEDAL AWARD FOR 1910

The John Fritz Medal was established by the professional associates and friends of John Fritz, Hon. Mem. Am. Soc. M. E., of Bethlehem, Pa., on August 21st, 1902, his eightieth birthday, to perpetuate the memory of his achievements in industrial progress. The Medal is awarded by a Board of sixteen, made up in equal numbers from the membership of the American Society of Civil Engineers, the American Institute of Mining Engineers, The American Society of Mechanical Engineers and the American Institute of Electrical

Engineers. It is awarded for notable scientific or industrial achievement, and there is no restriction on account of nationality or sex.

Awards of this medal to date have been made as follows:

The first (1905) to Lord Kelvin for his work in cable telegraphy and other scientific attainments.

The second (1906) to George Westinghouse for the invention and development of the air brake.

The third (1907) to Alexander Graham Bell for the invention and introduction of the telephone.

The fourth (1908) to Thomas Alva Edison for the invention of the duplex and quadruplex telegraph; the phonograph; the development of a commercially practical incandescent lamp; the development of a complete system of electric lighting, including dynamos, regulating devices, underground system protective devices and meters.

The fifth (1909) to Charles T. Porter for his work in advancing the knowledge of steam engineering and in improvements in engine construction.

The Medal for 1910 has been awarded to Alfred Noble, Mem. Am. Soc. M. E., for notable achievements as a civil engineer, and will be presented at a meeting to be held at the House of the American Society of Civil Engineers on the evening of Wednesday, November 30, 1910, at 8.30 p.m. All members of the four national societies and others who may be interested are invited to be present. Dr. Samuel Sheldon, Past-President, Am. Inst. E. E., now President of the Board of Award, will preside and addresses will be made by Isham Randolph, Mem. Am. Soc. C. E., of Chicago, Rossiter W. Raymond, Secretary Am. Inst. M. E., and others.

THE LATE WORK OF CHARLES T. PORTER

In The Journal for October appeared a short account of the important engineering services of the late Chas. T. Porter, which the profession recognized by presenting to him the John Fritz Medal in 1909. During the latter years of his life, Mr. Porter was in retirement, but he gave evidence from time to time that he had not altogether ceased his activities in the direction of improving the high-speed steam engine. In 1904 he presented to the Society four papers on an advanced form of high-speed engine, which he had built and tested, and, it is known that he hoped to complete a system of power development which would make it possible to obtain a horsepower on the evaporation of nine pounds of water per hour. Since his death his sons have gathered together his papers and put them in the hands of H. F. J. Porter who, with George H. Barrus, was associated with Charles T. Porter in his latest work. The former has revived the association of Mr. Barrus in this work, and has also enlisted the coöperation of Admiral Melville, who was greatly interested while Chief Engineer of the Navy in what Mr. Porter had developed for marine service. It is hoped that some way may now be found to make available the work of Mr. Porter in perfecting the high-speed engine, to which he gave the last twenty-five years of his life.

TRIBUTE TO DR. RAYMOND

A committee of members of the American Institute of Mining Engineers and other friends, which last April gave a dinner to Dr. Rossiter Worthington Raymond, in commemoration of his seventieth birthday, have issued an elaborate book, bound in morocco and beautifully decorated, containing the proceedings of that occasion in full detail. The volume opens with The Grand Canyon, a poem by Dr. Raymond, followed by photographs and sketches typifying important activities in his career, and copies of many letters of congratulation and engrossed resolutions from other societies. Dr. Raymond has for 26 years been Secretary of the Institute.

STUDENT BRANCHES

Activities for the season of 1910–1911 have recommenced in the Student Branches of the Society, as is evidenced by the following reports:

The University of Missouri has just held its election of officers, as a result of which H. W. Price is president, E. G. Spargo, secretary-treasurer, and Osmer Edgar, corresponding secretary. At the meeting on October 8, H. W. Price read a paper on Testing Gas Engines, which was followed by a general discussion relative to methods of speed adjustments, percentage of speed variations allowed, valve setting, order of firing, method of governing, gas consumption allowable, relative economy of producer and natural gas, and clearances allowed for producer gas, natural gas and gasolene.

At Pennsylvania State College, the Student Branch elected as officers: W. E. Heibel, president; D. C. Minick, vice-president, G. M. Forker, secretary and J. A. Hasseler, treasurer.

The prospects for the year at Purdue University are exceedingly bright, 72 new members having been enrolled during the past month.

At the September 14 meeting of the Stanford University Mechanical Engineering Association, Prof. W. F. Durand, Mem.Am.Soc.M.E., gave a talk on Hydraulic Power Developments in Switzerland. On September 28, the following officers were formally installed: honorary chairman, Prof. W. R. Eckart, Jr., Mem.Am.Soc.M.E.; chairman, J. B. Bubb; vice-chairman, E. L. Ford; secretary-treasurer, H. H. Blee.

The Stevens Engineering Society of Stevens Institute has announced its lecture course for the season, providing for bi-monthly lectures by prominent men. Dr. A. C. Humphreys, Manager Am.Soc. M.E., and President of the Institute, opened the series on October 18 with an address on Membership in Engineering Societies. Those who will speak at future dates are: Irving E. Moultrop, Manager Am.Soc.M.E.; James P. Haney, Director of Art in the High Schools of New York City; Donald B. MacMillan, who accompanied Peary to the Arctic Zone· Harvey W. Wiley, Chief of the Bureau of Chemistry, U. S. Dept. of Agriculture; Rossiter W. Raymond, Past-President and

Secretary, A.I.M.E.; David T. Day, Chief of the Bureau of Mines and Mineral Resources, U.S. Geological Survey; Gardner F. Williams, Life Member, A.I.M.E., associated for 18 years with Cecil Rhodes in South Africa; James Douglass, Past-President, A.I.M.E.; John A. Bensel, Commissioner, New York Board of Water Supply, and President A.S.C.E.; Carl Hering, Past-President A.I.E.E.; Frederick H. Newell, Director, U.S. Reclamation Service; William Campbell, Associate Professor of Metallurgy, Columbia University; A. Stanley Mackenzie, Professor of Physics, Stevens Institute; and George E. Hulse, Chief Engineer, Safety Car Heating and Lighting Company.

H. B. Dirks, Mem.Am.Soc.M.E., spoke to the University of Illinois Student Branch on September 30, on the Joint Meeting of the Society in England, at which he was present.

The University of Wisconsin, Madison, Wis., has elected the following officers: A. MacArthur, chairman; K. Kraatz, vice-chairman; A. Wegner, corresponding secretary, F. W. Braasch, assistant secretary; R. S. Moore, treasurer. Professor Thomas, Mem.Am.Soc.M.E. and Professor Christie, Assoc.Mem.Am.Soc.M.E., gave informal talks at the meeting of October 5, on the preparation of discussions of papers published in The Journal, and on the Joint Meeting,.

At a dinner of the Student Branch of the Massachusetts Institute of Technology on October 13 plans were laid for a trip to Buffalo and Niagara Falls. Professors Lanza, Miller and Hayward of the department of Mechanical Engineering were the speakers for the evening.

The Council has authorized the establishment of a student branch at the Sheffield Scientific School, Yale University, under the name of The Yale Mechanical Engineers' Club, Affiliated with The American Society of Mechanical Engineers. The student branch now has a membership of 29, with W. Roy Manny as secretary.

MEETING OF THE COUNCIL

The regular Meeting of the Council was held on the afternoon of Tuesday, October 11, 1910, in the Society rooms, with Vice-President Baker in the chair. There were present Chas. Whiting Baker, George M. Bond, H. L. Gantt, Alex. C. Humphreys, James Hartness, I. E. Moultrop, H. G. Reist, F. M. Whyte, Wm. H. Wiley, Treasurer, Arthur M. Waitt, Chairman of the Finance Committee, and the Office Manager representing the Secretary. Regrets were received from W. F. M. Goss, E. D. Meier and R. C. Carpenter.

The minutes of the meeting of May 31 were read and approved. The Secretary reported the following deaths: Mark Bary, Chas. B. Clark, Barton Cruikshank, W. P. Bettendorf, W. E. Crane, J. D. E. Duncan, James B. Faulks, Chas. H. Ferry, C. E. Foster, Joseph Garbett, Jno. E. McKay, Albert Spies, Chas. T. Porter.

The following resignations were accepted: Thos. C. Perkins, Chas. E. Jones, R. B. Hart, Thos. Appleton, Frank R. Chambers, Jr., Warren S. Locke.

Notice was given of the purpose to elect to life membership under the provisions of C 23, S. B. Whiting of Cambridge, Mass., Charter Member of the Society, and of W. F. Mattes of Scranton, Pa.

Voted: To approve the appointment of Honorary Vice-Presidents: National Irrigation Congress, Pueblo, Colo., Sept. 26–30, C. H. Williams of Denver, Colo.; Second National Conservation Congress, St. Paul, Sept. 5–9, Paul Doty, J. J. Flather, L. H. Gardner, E. E. Johnson and M. E. R. Toltz; Inauguration of President McVey, University of North Dakota, Grand Forks, Prof. Calvin H. Crouch; American Mining Congress, Los Angeles, Cal., Sept. 26-Oct., 1. H. H. Clark and Robert Linton; Funeral of Charles T. Porter, Honorary Member, Alex. C. Humphreys, Hosea Webster, A. E. Forstall and J. E. McIntosh.

Voted: To confirm the action of the Executive Committee in declining under the provisions of C 56 the request of the Good Roads Association to participate with them in the securing of legislation favorable to promoting the improvement of public highways for interstate travel, military uses, etc., as provided in H. R. Bill 25,333 introduced by Representative Cocks.

Voted: To confirm the action of the Executive and Finance committees as outlined in the letter of the Secretary, July 5, 1910, approving an additional appropriation of $3500 for the Publication Committee, and the transfer of $300 from the Power Tests Committee to the Meetings Committee.

Voted: To approve the list of candidates recommended for the several grades of membership, as given in the minutes of the Membership Committee Sept. 14, 1910, and to confirm the action of the Executive Committee in ordering posted the names of all approved candidates.

Report was made of the questions which had arisen with the Post Office Department in the matter of securing second-class entry of The Journal.

Voted: To refer the matter back to the Publication Committee for further report.

Voted: To accept with thanks of the Council the progress report of the Research Committee and suggest that the matter be elaborated for presentation at the annual meeting.

Voted: To accept the report of the House Committee as presented by Mr. W. C. Dickerman, Chairman, and to express the thanks of the Council for their work during the past year.

The following vote of the Meetings Committee was read:

> That the Council be requested to approve the appointment of a sub-committee of the Meetings Committee to consist of five members of the Society, to be known as the Committee on Economic Administration of Industrial Establishments, and to consist largely if not entirely of members holding administrative positions in such establishments. The duties of the Committee are to consist of the solicitation of papers on this subject, the judging of papers received, and their transmission, with their opinion, to the Meetings Committee; also to serve as a board of supervisors to the Meetings Committee on all questions relating to this subject.

Voted: To approve the appointment of a sub-committee of the Meetings Committee, and the committee be directed to proceed under the provisions of By-Law 23.

Voted: That the date set for the next monthly meeting of the Society, November 9, be also the date for a meeting of the Council.

Voted: To accept the progress report of the Research Committee and especially request that it be elaborated and with the valuable data obtained presented at the Annual Meeting Membership Committee.

Voted: On recommendation of the Membership Committee to approve the reinstatement of C. H. Hurd of Indianapolis, Ind., who resigned from membership in 1907.

Voted: To decline the application for Student Membership of the State University of Kentucky, Lexington, Ky.

Voted: To approve the application of Sheffield Scientific School, Yale, to form a student branch, to be known as Yale Mechanical Engineers' Club affiliated with The American Society of Mechanical Engineers.

Voted: To refer jointly to the Finance and Meetings committees consideration, with the Boston members, of the proposed plans for an engineering building in Boston and what part if any the Society can take.

Dr. Humphreys reported progress in the matter of the appointment of a Public Relations Committee.

Mr. Arthur M. Waitt, Chairman of the Finance Committee presented the following resolutions from his Committee which were approved:

That in view of the increase in the amount received from sales of publications from the estimate of $5000 to $9282, entailing an expense of $1401.28 above the appropriation, this amount to credited to the sales expenditure account from the excess of income for the year 1909–1910.

To cancel the balances of all other appropriations for 1909–1910 after reserving $4200 for the completion by the Publication Committee of Vol. 31 Transactions, all changes in appropriation being within the current income for the year.

To appropriate from current income for 1909–1910, $228.29 for the advances preliminary to the advertising of The Journal.

To transfer from current income to the Reserve Fund, $2400 to reimburse the Reserve Fund for all expenditures from that fund on account of the London Meeting during the fiscal year 1909–1910; and to approve the expenditure of $653.44 that has been made from current income on account of the London Meeting, thus providing the payment from the current income of this year of all expenses for the London Meeting incurred up to date.

That the action of the Council of October 24, 1906, relative to the disbursements from Land Fund, be rescinded now, so far as interest on the mortgage is concerned, and that in the future the interest on the Carnegie mortgage be included in the appropriations to be paid from current income.

To approve the budget as presented and to express the appreciation of the Council to the Finance Committee for the splendid financial showing for the year's work.

On motion meeting adjourned.

NECROLOGY

FREDERICK MERIAM WHEELER

Frederick Meriam Wheeler of Montclair, N. J., a charter member of the Society, died at his summer home in Westhampton, Long Island, on September 15, 1910.

Mr. Wheeler, who was born in Brooklyn, N. Y., in 1848, was graduated from Summit Academy in New Jersey, and subsequently attended the Polytechnic Institute, Brooklyn, N. Y. His early apprenticeship was served in the machine shop of the Lake Mills, Lake Village, N. Y., and he later studied mechanical engineering for five years under Henry J. Davison of New York City. He made hydraulic and marine engineering his specialty and for over thirty-four years was associated with the George F. Blake Manufacturing Company, of which he became director and secretary. When the company was absorbed by the International Steam Pump Company, together with other hydraulic works, Mr. Wheeler was made a director in the new company.

Mr. Wheeler was the inventor of the Wheeler surface condenser which is extensively used in this country and Europe and has been adopted by the United States Navy. He organized the Wheeler Condenser and Engineering Company, with works at Carteret, N. J., and was also officially connected with the Ludlow Valve Manufacturing Company.

In addition to his membership in the Society, Mr. Wheeler was a charter member of the Society of Naval Architects and Marine Engineers, and was also a member of the American Society of Naval Engineers and of the Engineers Club of New York. He served as a member of the advisory council of the Engineering Congress at the Columbian Exposition in 1892, and had for many years been prominent in public and social circles in his home city.

BARTON CRUIKSHANK

Dr. Barton Cruikshank, a member of the Society, was drowned in the St. Lawrence River on June 27, 1910, where he was conducting a boys' summer school and camp at Cedar Cliff, N. Y.

Dr. Cruikshank, who was born in Albany, N. Y., February 5, 1866, was educated in the public schools and Adelphi Academy of Brooklyn and in the Brooklyn Polytechnic Institute, where he received the degree of B. S.

After graduation he entered the shops of the Brady Manufacturing Company, in which he soon rose to be superintendent and assistant manager, finally becoming president. From there he went to Boston in the employ of the Boston Heating Company, and later to Princeton, N. J., as instructor in graphics and mathematics in the university. In 1891–1892 he acted as consulting engineer for the Indurated Fibre Pipe Company in New York, and in 1893 became superintendent of the Hammond Typewriter Company, Brooklyn. During his residence there, Dr. Cruikshank assisted Dr. Larkins in starting and organizing the first manual training high school in Brooklyn.

In 1899 he accepted the presidency of the Clarkson School of Technology at Potsdam, N. Y., from which he resigned in 1902 to become president of the Cogswell Polytechnic College in San Francisco. Two years later he returned to the East, entering the employ of the Solvay Process Company in Syracuse, N. Y., as designing engineer, where he remained until a year before his death when he took up the organization of his boys' camp, which was so unfortunately the scene of his sudden death.

CLAY BELSLEY

Clay Belsley, a member of the Society, died at his home in Peoria, Ill., on September 3, 1910. Mr. Belsley was born at Spring Bay, Ill., on January 28, 1873, and was graduated from Cornell University in 1898 with the degree of M.E. Soon afterward he entered the employ of the Link-Belt Company of Chicago, where he had charge of the mining machine plants. He later entered the service of the McEntee-Peterson Engineering Company of Peoria, by whom he was placed in sole charge of their work in the South, including the building of the electric light plant at Gastonia, N. C. In 1901, Mr. Belsley returned to Peoria and opened a private practice as consulting engineer.

Among other important work undertaken at this time, he designed an electric light and power plant for Tom J. Gardner at Las Animas, Colo., installed the mechanical and electrical plant of the Corning distillery, and had charge of the design and construction of all the work of the Woodruff Ice Company of Peoria. He was also engaged during this period in expert investigation in connection with legal work.

In 1908, Mr. Belsley accepted the appointment of City Engineer of his native city, resigning his lucrative private practice to perform this public service. While personally superintending the construction of a masonry culvert for the city, he contracted typhoid fever and from the resulting weakened condition never recovered.

ALFRED WILKINSON

Alfred Wilkinson, who died at his home in Bridgeport, Pa., on August 30, 1910, was born at Stockport, in Cheshire, England, May 17, 1845. Here he attended the common schools and the Mechanics Institute. When fourteen years of age he came to the United States, entering the Richmond shops of the Philadelphia and Reading Railroad Company where he remained till 1862. When the Civil War broke out he enlisted in the navy and served under Admiral Farragut, being promoted for meritorious service to third assistant engineer. At the close of the war he entered the employ of Carr, Crawley and Devlin, Philadelphia. In 1876 he opened an office of his own in Philadelphia as expert steam engineer, and in 1891 invented the automatic mechanical stoker which today bears his name and which is extensively used on ocean liners and in large manufacturing plants. In the same year Mr. Wilkinson organized the Wilkinson Manufacturing Company at Bridgeport, Pa., and began the manufacture of his invention. He was at the time of his death president of the company.

Besides being a member of this Society, Mr. Wilkinson was a member of the Franklin Institute and the Manufacturers' Club of Philadelphia. He inherited his mechanical genius from his father, Joseph Wilkinson, who invented a cook stove and an automatic oil cup for steam engines.

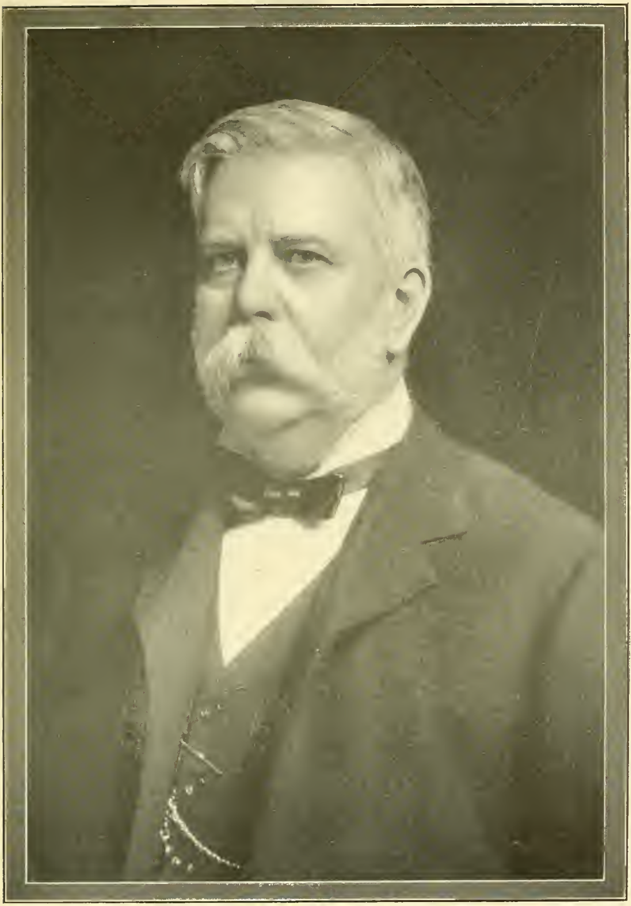
THE JOINT MEETING IN ENGLAND

ACCOUNT OF THE JOINT MEETING OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS WITH THE INSTITUTION OF MECHANICAL ENGINEERS

Birmingham and London, 1910

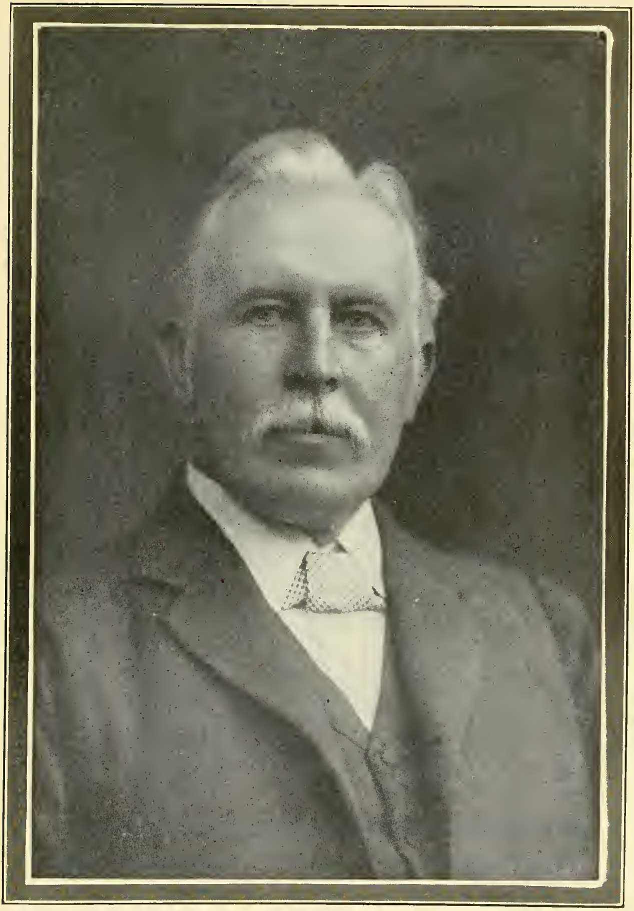
By Calvin W. Rice, Secretary

The American Society of Mechanical Engineers



GEORGE WESTINGHOUSE, PRESIDENT

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS



JOHN A. F. ASPINALL, PRESIDENT

THE INSTITUTION OF MECHANICAL ENGINEERS

THE JOINT MEETING IN ENGLAND

By Calvin W. Rice

TABLE OF CONTENTS

Page

Officers and Council of the A.S.M.E. 1703

Committee of Arrangements 1704

Official Party 1705

Other Members and Guests in Attendance 1707

Officers and Council of the Institution 1708

Birmingham Reception Committee 1709

Members of the Institution in Attendance 1709

Invitation from the Institution and Acceptance 1712

Arrangements for Trip 1714

Events on Shipboard 1715

Welcome in Liverpool and Arrival in Birmingham 1721

Dinner given by President Aspinall 1723

Opening of the Joint Meeting:

- Welcoming Addresses 1724
- Presentation of Watt Letter 1725
- Papers on Locomotive Terminals 1726

Excursions and Trips 1726

Garden Fête 1730

Second Professional Session:

- Telegram from Mr. Westinghouse 1730
- Papers on High-Speed Tools and Tooth Gearing 1731
- Resolutions of Thanks 1731

Excursions and Trips 1732

Reception in the Council House 1733

Departure from Birmingham 1734

Excursions 1734

Conversazione in Institution House 1744

London Professional Session:

- Address of Welcome 1745
- Papers on Electric Traction 1745
- Resolutions of Thanks 1745

Garden Parties and Visits 1747

Institution Banquet 1747

Trips to Windsor and Marlow 1748

Dinner given by Sir Wm. H. and Lady White 1749

Service in Westminster Abbey 1749

Dinner given by Mr. Swasey 1750

Conclusion of Meeting 1750

OFFICERS AND COUNCIL OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

President

George Westinghouse, Pittsburg, Pa.

Vice-Presidents

Geo. M. Bond, Hartford, Conn.
F. M. Whyte, New York
W. F. M. Goss, Urbana, Ill.
R. C. Carpenter, Ithaca, N. Y.
Charles Whiting Baker, New York
E. D. Meier, New York

Past-Presidents

John R. Freeman, Providence, R. I.
F. R. Hutton, New York
Frederick W. Taylor, Phila., Pa.
M. L. Holman, St. Louis, Mo.
Jesse M. Smith, New York

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I. E. Moultrop, Boston, Mass.
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James Hartness, Springfield, Vt.
H. G. Reist, Schenectady, N. Y.

Treasurer

William H. Wiley, New York

Chairman of the Finance Committee

Arthur M. Waitt, New York

Secretary

Calvin W. Rice, 29 West 39th Street, New York

COMMITTEE OF ARRANGEMENTS

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Chas. Whiting Baker, *Vice-Chairman*
Geo. M. Brill
John R. Freeman
W. F. M. Goss

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F. R. Hutton, Honorary Secretary
William H. Wiley, Treasurer
Calvin W. Rice, Secretary
Willis E. Hall, Chairman Meetings Committee

Sub-Committee on Entertainment

George M. Brill, *Chairman*
Mrs. George M. Brill
George A. Orrok
Mrs. F. R. Hutton
Mrs. Jesse M. Smith

Sub-Committee on Printing and Publication

F. R. Hutton
F. R. Low

Sub-Committee on Acquaintanceship

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H. R. Cobleigh
Wm. C. Dart
James M. Dodge
H. L. Gantt
A. M. Greene, Jr.
F. R. Hutton
C. T. Plunkett
F. H. Stillman
Worcester R. Warner

Sub-Committee on Transportation

Charles Whiting Baker
Calvin W. Rice

Sub-Committee on Finance

William H. Wiley

Sub-Committee on Sports

Spencer Miller, *Chairman*
Karl Dodge
Alex. W. Moffat
Theodore Main
Spencer Miller, Jr.

MEMBERS AND GUESTS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS IN ATTENDANCE

Official Party Sailing on White Star S.S. Celtic

PAST-PRESIDENTS

Dodge, James M., Philadelphia, Pa.
Freeman, John R., Sc.D., Providence, R. I.
Hutton, F. R., C.E., M.E., Ph.D., Sc.D., New York
Smith, Jesse M., New York
Smith, Oberlin, Bridgeton, N. J.
Swasey, Ambrose, Dr. Eng., Sc.D., Cleveland, Ohio
Warner, Worcester R., Dr.Mech.Sc., Cleveland, Ohio

VICE-PRESIDENT

Goss, W. F. M., Dr.Eng., Urbana, Ill.

MANAGERS

Gantt, Henry L., New York
Hartness, James, Springfield, Vermont

TREASURER

Wiley, William H., M.C., New York

HONORARY SECRETARY

Hutton, F. R., C.E., M.E., Ph.D., Sc.D., New York

Secretary

Rice, Calvin W., New York

Commander, A. E. S. Hambelton, Lieut. R.N.R.
Surgeon, A. Hopper
Purser, G. H. Brewer
Chief Steward, G. Roberton
Asst. Purser, L. L. Delacour
Chief Engineer, C. C. Lapsley

Adams, Miss, New York, with Hon. and Mrs. Wm. H. Wiley
Aldrich, John G., Providence, R. I.
Alford, L. P., New York
Alford, Mrs., New York
Armstrong, Miss, Elizabeth, N. J., with Mr. and Mrs. S. L. Moore
Baldwin, Abram T., Detroit, Mich.
Barnes, Howel H., Jr., New York
Bevin, Sydney, Walden, N. Y.
Bevin, Mrs., Walden, N. Y.
Brill, Geo. M., Chicago, Ill.
Brill, Mrs., Chicago, Ill.
Brill, Elliot M., Chicago, Ill.
Brill, G. Meredith, Chicago, Ill.
Brooks, J. Ansel, Providence, R. I.
Bump, Burton N., Syracuse, N. Y.
Bump, Mrs., Syracuse, N. Y.
Burlingame, L. D., Providence, R. I.
Burlingame, Mrs., Providence, R. I.
Burlingame, Miss, Providence, R. I.
Bursley, Jos. A., Ann Arbor, Mich.
Bursley, Mrs., Ann Arbor, Mich.
Calder, John, Ilion, N. Y.
Calder, Mrs., Ilion, N. Y.
Camp, Geo. E., Utica, N. Y.
Clarke, C. W. E., New York
Cobleigh, H. R., New York
Coffin, Mrs. Charles H., New York, with Mr. and Mrs. Jesse M. Smith

Corbett, Charles H., Brooklyn, N. Y.
Corbett, Mrs., Brooklyn, N. Y.
Dart, Wm. C., Providence, R. I.
Davis, Chas. Ethan, Muncie, Ind.
Davis, Mrs., Muncie, Ind.
Dean, F. W., Boston, Mass.
Dodge, Mrs. James M., Philadelphia, Pa.
Dodge, Miss, Philadelphia, Pa.
Dodge, Karl, Philadelphia, Pa.
Durfee, Walter C., Jamaica Plain, Mass.
Durfee, Miss, Jamaica Plain, Mass.
Foster, Miss, New York, with Mr. and Mrs. Augustus Smith
Freeman, Mrs. John R., Providence, R. I.
Galloupe, Francis E., Boston, Mass.
Galloupe, Chauncy Adams, Boston, Mass.
Gantt, Mrs. H. L., New York
Gilbreth, Frank B., New York
Gleason, Wm., Rochester, N. Y.
Goss, Mrs. W. F. M., Urbana, Ill.
Goss, Miss, Urbana, Ill.
Greene, Arthur M., Jr., Troy, N. Y.
Greene, Mrs., Troy, N. Y.
Hallenbeck, Geo. E., Toledo, Ohio
Hamilton, Chester B., Jr., Toronto, Can.
Hartness, Mrs. James, Springfield, Vt.
Hartness, Miss, Springfield, Vt.
Hartness, Miss Helen E., Springfield, Vt.
Higgins, C. P., Roselle, N. J.
Higgins, Mrs., Roselle, N. J.
Hillyer, Geo., Jr., Atlanta, Ga.
Honsberg, August A., Cleveland, Ohio
Hutton, Mrs. F. R., New York
Johnson, A. L., Muncie, Ind.
Johnson, Mrs., Muncie, Ind.
Keep, W. J., Detroit, Mich.
Keep, Mrs., Detroit, Mich.
Keep, Miss, Detroit, Mich.
Klepinger, J. H., Great Falls, Mont.
Klepinger, Mrs., Great Falls, Mont.
Klock, Frank B., Syracuse, N. Y.
Latham, H. M., Worcester, Mass.
Leland, Henry M., Detroit, Mich.
Leland, Mrs., Detroit, Mich.
Lewis, Wilfred, Philadelphia, Pa.
Lodge, William, Cincinnati, Ohio
Lodge, Mrs., Cincinnati, Ohio
Low, F. R., New York
Low, Mrs., New York
McCreery, J. H., New York
Main, Charles T., Boston, Mass.
Main, Mrs., Boston, Mass.
Main, Miss, Boston, Mass.
Main, Theodore, Boston, Mass.
Marburg, L. C., New York
Miller, Spencer, New York
Miller, Spencer, Jr., New York
Moore, S. L., Elizabeth, N. J.
Moore, Mrs., Elizabeth, N. J.
Morrin, Thos., San Francisco, Cal.
Morrin, Mrs., San Francisco, Cal.
Nelson, James W., New York
O'Neil, J. G., Chicago, Ill.
O'Neil, Mrs., Chicago, Ill.
Orrok, Geo. A., New York
Parson, Charles H., New York
Parson, Mrs., New York
Platt, John, New York
Plunkett, Charles T., Adams, Mass.
Plunkett, Chas. T., Jr., Adams, Mass.
Reed, E. Howard, Worcester, Mass.
Reed, Mrs., Worcester, Mass.
Reid, Joseph, Oil City, Pa.
Richmond, Knight C., Providence, R. I.
Roe, J. W., New Haven, Conn.
Sague, J. E., Albany, N. Y.
Sague, Mrs., Albany, N. Y.
Sague, Miss, Albany, N. Y.
Sanford, Geo. R., Syracuse, N. Y.
Scott, Charles F., Pittsburg, Pa.
Smith, A. Parker, New York
Smith, Mrs., New York
Smith, Augustus, New York
Smith, Mrs., New York
Smith, Mrs. Jesse M., New York
Smith, Mrs. Oberlin, Bridgeton, N. J.
Stillman, F. H., New York
Stillman, Mrs., New York
Struckmann H., St. Louis, Mo.
Struckmann, Mrs., St. Louis, Mo.
Such, Miss, New York, with Mr. and Mrs. Augustus Smith
Swasey, Mrs. Ambrose, Cleveland, Ohio
Thompson, B. L., Syracuse, N. Y.
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THE JOINT MEETING, 1910

By Calvin W. Rice, Secretary

The American Society of Mechanical Engineers

In the Spring of the year 1909, Sir Robert Hadfield, a member of the Council of the Institution of Mechanical Engineers, brought to The American Society of Mechanical Engineers, on one of his frequent trips to America, the first intimation of a Joint Meeting to be held in England the summer of the following year. This was confirmed in September by the following formal invitation from our sister organization:

The Institution of Mechanical Engineers

Storey's Gate, St. James Park, Westminster, S. W.

17th September, 1909.

Dear Mr. President:

At a Meeting of the Council of this Institution held today, the following Resolution was unanimously passed:

"That a very hearty invitation be sent to The American Society of Mechanical Engineers to participate in a Joint Meeting in England with the Institution of Mechanical Engineers, and that the Meeting be held in the Summer of 1910, if possible during the last week in July."

I need scarcely say how warmly the subject was supported by those present, especially as the Council had learnt from the Committee appointed to confer with Mr. H. deB. Parsons, the special representative of your Society, the cordiality with which the idea had been taken up by your Members.

We hope that we may be favored with the presence of yourself, your Council, and many of your Members at the proposed Meeting.

With all good wishes, we are,

Yours very truly,
John A. F. Aspinall
President
Edgar Worthington
Secretary

The President
The American Society of Mechanical Engineers
29 West 39th Street, New York, U. S. A.

Former gatherings of a like nature had taught not only the value, but also the great pleasure to be derived from such a meeting of the two national mechanical engineering organizations, and by the unanimous vote of the Council of the Society the following reply was despatched:

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS
29 West 39th Street, New York, U. S. A.

Dear Mr. President:

The Council of The American Society of Mechanical Engineers has considered the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the Summer of 1910, conveyed by your letter of September 17.

The Council was unanimous in the acceptance of the invitation and bids me convey to you its action as follows:

"Resolved,—That The American Society of Mechanical Engineers accept the very cordial invitation of The Institution of Mechanical Engineers, to hold a joint meeting in England in the Summer of 1910. The Council feels that the interests of Engineering throughout the World will assuredly be advanced by the giving and the acceptance of this invitation;—an evidence of an increasing coöperation among the various societies representing the Profession of Engineering."

In conveying this resolution of the Council permit us to inform you of the universal cordiality with which the invitation has been received both by the Council and by the Members of the Society. It is the expectation that a representative delegation of the Society will be present at the meeting.

Please accept our expressions of sincere good will.

JESSE M. SMITH
President
CALVIN W. RICE
Secretary

To The President
The Institution of Mechanical Engineers
London, England

The preliminary work of announcing this action to the membership was assigned to the Executive Committee of the Council as well as the tentative arrangements for transportation, whereby an option, expiring March 1, was secured upon the entire first cabin of the White Star Steamship Celtic, sailing July 16 for Liverpool.

The Committee of Arrangements immediately upon its appointment by the Council in the Spring of 1910 took up the task of perfecting these and other details, producing, under the able Chairmanship of Ambrose Swasey, Past-President Am.Soc.M.E., a result which made this meeting an event in the history of the Society.

NEW YORK TO BIRMINGHAM

The Celtic with the official party of 144 members and guests steamed from the White Star dock in the North River at two o'clock in the afternoon of July 16, under a cloudless sky, good augury of the voyage ahead. The Committee on Acquaintanceship which, with the characteristically energetic generalship of Dr. W. F. M. Goss, met immediately after dinner the same evening and remained continuously on duty until the end of the voyage, soon made the individual members of the party known to one another. Invitations, on which was embossed and colored the emblem of the Society, were also issued to the other members of the first cabin, cordially urging their participation in the events arranged for the week on shipboard, a thoughtful act suggested by Professor Hutton and Mr. Brill which was greatly appreciated. The entire group was thus at once brought into a friendly relationship not usually secured until the end of the journey.

The first day out, which was Sunday, was spent quietly in resting and visiting, religious services being conducted by the Right Reverend William D. Walker, Bishop of Western New York. On Monday, preliminary games were begun on deck. In the evening the officers and past-presidents of the Society, together with the officers of the Celtic, received the first cabin passengers on the upper promenade deck, thus bringing the party and the other voyagers into closer acquaintance. This is believed to be the first occasion in the history of the Celtic, if not of the steamship line, in which the officers of the ship participated in receiving the passengers. A dance followed the reception.

The lecture given on Tuesday evening by Worcester R. Warner, Past-President, on What are the Astronomers Doing, was not only entertaining but instructive, and was finely illustrated by lantern views, many of which were new and shown for the first time to any audience.

The musicale arranged for Wednesday evening proved one of the most enjoyable features of the trip, displaying to advantage the versatility of the Society's membership. The success of those in charge in enlisting the participation of the other passengers was exemplified in the acceptance of the chairmanship of the evening by Mr. Everett P. Wheeler, well-known in legal and political circles in New York City. The program follows:

Selection Guglielmo Tell .... Rossini
Orchestra
Vocal Solos *a* The Flower Song from Faust.... Gounod
b Ask Me no More.................. Tosti
Miss Grace Burlingame
Cello Solos *a* Romance .... Davidoff
b Largo .... Handel
Dr. Leonard Waldo
Monologue The Village Dressmaker.......... Wiggin
Mrs. Jesse M. Smith
Vocal Solos *a* The Skipper of St. Ives.......... Roeckel
b Three for Jack .... Squire
D. J. Edmonds
Piano Solo Song Without Words.......... Mendelsohn
Miss Alice M. Main
Reading The Limerick Tigers.............. Edwards
Prof. F. R. Hutton
Selection Three Dances Henry VIII........ German
Orchestra

The appreciation felt by the first cabin passengers of the entertainments arranged by the Society was expressed by Mr. Wheeler at the conclusion of the musicale.

On Thursday evening, John R. Freeman, Past-President, gave an interesting illustrated address on the Construction of the Panama Canal, of which it is well known Mr. Freeman speaks with authority through his official connection with the Board of Engineers appointed by President Taft to visit the canal in 1909. Slides of a different character were afterward thrown on the screen, showing among other views a portrait of Captain Hambelton, and a reproduction of the menu card of the dinner given by Ambrose Swasey, then President of the Society, at the time of the last visit of the Institution to America in the year 1904. As the words of God Save the King were shown, the audience joined in singing the British national song. Friday evening was devoted to dancing.

A bridge-whist contest was held Thursday afternoon, and on Friday the sports took place, miscellaneous games being also in progress, during the entire week. Saturday evening had been set apart for the awarding of prizes to the winners of these various tests of skill and for a gathering of a more informal nature than those of preceding evenings. Prof. F. R. Hutton presided over the occasion, and after an orchestra had rendered a selection, Geo. M. Brill, Chairman of the Entertainment Committee, announced the following awards: 1st prize in bridge-whist, to J. D. C. Darrell, a pair of flat brushes in a leather case; 2nd prize, to John Calder, a pigskin traveling case for collar buttons, etc.; 3rd prize, to Mrs. W. K. Carr, a hat pin; 4th prize, to Mrs. M. B. Orde, a bridge set; 1st prize in shuffleboard contest, to Karl Dodge, "Satchel Guide to Europe"; 2nd prize, to Theodore Main, "My Trip Abroad"; to the winner of the pillow fight, H. M. Klingenfeld, a knife on a small pillow; to the winner of the men's potato race, A. Wise, a coin purse; of the ladies' potato race, Miss H. E. Armstrong, a silver coin holder, and Miss Gertrude Baker, a silver pencil; and to the winner of the obstacle race, Karl Dodge, a coin purse. A so-called endurance prize, a fan, was also given to Mrs. Jesse M. Smith, the last lady to stay in the game of shuffleboard. A consolation prize, consisting of a doll, was contributed by friends to Frank B. Gilbreth, who lost in the final round of shuffleboard, and also as a mark of appreciation of his efficient service as Chief of Police in maintaining order during the games. Prof. F. R. Hutton received a loving cup, of the telescopic variety. As each winner came forward to receive his or her prize, a speech was demanded, thus eliciting a number of impromptu remarks which greatly added to the merriment of the evening. Most of these prizes, chosen with characteristic good taste, had been appropriately engraved or stamped with the name of the Society and the occasion, through the thoughtfulness of Mr. and Mrs. Brill.

James M. Dodge, Past-President, followed with a humorous lecture, entitled An Exhaustive Review of the Formation of the Earth and its Oceans, with Some Conclusive Educational Remarks on the Solar System and Prognostications on the Ultimate End of the Universe, in which he assumed to controvert the theories of all other scientists. A jury consisting of Ambrose Swasey, John R. Freeman, William H. Wiley, Oberlin Smith, Jesse M. Smith, George M. Brill, Calvin W. Rice, H. L. Gantt, Prof. W. F. M. Goss, Prof. Arthur M. Greene, Jr., James Hartness and F. H. Stillman, had been chosen to sit in judgment on his arguments and, clad in the robes of office, filed in with due solemnity as Mr. Dodge began his address. Mrs. E. B. Danforth, eighty years of age, then rendered a piano solo, and A. T. Baldwin read the following "Engineer's Reverie," written by Granger Whitney, Superintendent of the Detroit Iron and Steel Company, a member of the Detroit Engineering Society:

WHAT'S THE USE

By Granger Whitney, Detroit, Mich.

What's the use of running levels on a hillside that is steep?
What's the use of building railroads through the valleys that are deep?
With your cantilever bridges, with record breaking spans,
Your aids to navigation, your ship locks and your dams.
Oh, the hydrostatic pressure at the Sault, it gives me chills,
And the dusty, smoking tunnel running through the Hoosac hills
Makes me weary with existence; the canal at Panama
Seems a labor of utility thats hardly up to par.
Oh—What's the use?

What's the use of doubling up your work on multiple machines
Till the weary brain is pinioned to a rack of grasping schemes?
Your indicator card will show expansion of the head,
Exhaustion of the intellect, the cut-off finds you dead.
With monoplane and gasolene you navigate the air,
Your differential valve gear drives a man to deep despair,
With many new inventions you strive till you obtain
The ecstatic culmination of an epicylic train.
Oh—What's the use?

What's the use of sinking shafts six thousand feet at Calumet?
What's the use of stoping out the Colorado sulphurets?
Now it's conical drum engines and ventilating fans,
Then the cyaniding process and amalgamating pans,
Steam shovels do your digging in a most efficient way,
Six hundred tons of Bessemer you're smelting in a day.
It's economy and saving with gas seal and double bell,
Eighty-five percent Mesabe and your tops blown all to hell.
Oh—What's the use?

What's the use of putting bilge keels on an ocean going ship,
Let her roll and let the lubbers seek their bunks or miss the trip.
There's forced draft on your boilers, you have sixty feet of beam,
You move with two propellers and a trinity of steam.
With twelve-foot center hatches and twelve thousand tons below
How your rivets groan and tremble when the wind comes on to blow.
Three days from Escanaba to Conneaut, your goal,
And there you fuss and fidget till you're sailing north with coal.
Oh—What's the use?

If you're going to be a pessimist there isn't any use
Of building ships or mining ore or generating juice.
If your ultimate ambition is to roll a ton of rails,
To build an automobile or to make a keg of nails
You will find that life's a burden, you will find existence stale,

If you live by rule and precedent you pretty sure will fail,
And if you only work and sleep and take three meals a day
Why there isn't any answer and it really doesn't pay.
So—What's the use?

It's the friends you've got in Denver, it's your life out on the hills,
It's the men you met at Panama, your record with the drills,
It's the girls you've met on ship board at Harrisburg, the friends you left at home,
It's that plutocratic feeling when you're hiking down from Nome.
It's the people up in Scranton, it's the folks you met in Lynn,
It's your cronies out in Pueblo, it's the places you have been,
It's the life you led at Phoenix when you crossed the great divide,
It's the work you did at Jarrow, it's your record on the Clyde.

It's the golf you played at Birmingham, your San Francisco spree,
It's when you saw the springtime clothe the hills of Tennessee,
It's the drinks you drank in Pittsburg in your youthful days of joy,
It's that forty mile excursion from Schenectady to Troy,
It's the days you spent in Helena, your luck at Cripple Creek,
It's the gang at South Chicago that never went to sleep,
It's the fellows at Altoona, it's the men that sing and laugh,
It's the men you've known and lived with from Newport News to Bath.

It's when the day is over and your work is all well done,
It's when the campaign's ended, it's when the battle's won,
Then friendship keen, and memory of many happy days
Bring the glorious satisfaction that a life of action pays.
That's the use—That's the use—
And we'll drink a toast to energy and raise a merry song,
We'll lead a life that's strenuous, we'll work a day that's long.
And when that day is ended and our work is damned well done
We'll meet around the festal board, we'll have a little fun.
That's the use.

Ambrose Swasey, Chairman of the Committee of Arrangements, expressed briefly the Society's appreciation of the courtesy and friendliness of the ship's officers, which had added so much to the week's voyage, and as a memento of the trip presented to Captain Hambelton a silver case, beautifully chased and engraved with the words, PRESENTED TO CAPTAIN A. E. S. HAMBELTON, COMMANDING S. S. CELTIC, BY MEMBERS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, JULY 23, 1910; and to Chief Engineer Lapsley an electric desk lamp, with Tiffany favrile glass shade, similarly engraved. These tokens came as a great surprise to their recipients, who expressed their thanks in a few graceful remarks.

Professor Hutton brought the program to a close with the following poem written by him for the occasion:

AN - ODE; WITH KATH - ODE

By F. R. Hutton, New York

Honorary Secretary of the Society

THE AN—ODE

There once was a "Gang" transatlantic
Up to all sorts of lark and of antic;
  The Celtic's so steady
  That each one is ready
For play, spite of sea rough and frantic.

They have heard about comet and star,
In dancing, they've scampered afar,
  At the "Tigers" they've smiled,
  Been by "Bell-buoy" beguiled,
And learned, too, about Panama.

We have Swasey to act as our Boss,
We have chuckled with Hartness and Goss,
  And with Miller, (T. Spencer),
  As stunt-scheme dispenser
The trip's end seems much like a loss.

One lad used a big megaphone;
Perched aloft, with a loud brassy tone,
  He told us who scored
  When they played shuffle-board
With a glee which is just Dodge's own.

One uses a lot of his breath
We all like to hear what he saith:
  His nonsense is fine
  I wish like it for mine
But can he be "wasting," Gilbreth?

Nor must we forget our police
So great in preserving the peace;
  Were "face-making" a crime,
  Then "gum-chewing's" sublime,
And grave misdemeanours must cease.

THE KATH—ODE

We seem to be nearing the shore
When our larks for a while will be o'er
But we'll never forget;
And the friends we have met
Will be mem'ries of joy ever more.

So here on our last festal night
And with Ireland almost in sight,
We sing "Hail to the Chief"!
(To Lapsley, in brief)
Who has handled our engines' great might.

But to Hambelton—bless heart and head—
Our last friendly word shall be said:
"Good luck" and "Good-bye,"
We unite in the cry:
From the sea he has lifted all dread.

After singing My Country 'tis of Thee, appropriately followed by God Save the King, the company dispersed amid many expressions of appreciation. During the evening a collection was taken for the Seamen's Charities of Liverpool and London.

The program of Saturday evening, which was characterized throughout by a spirit of goodfellowship, brought to a close the unique and delightful series of events provided by the Committee on Entertainment, to whom as well as to the general committee so much of the pleasure of the trip was due. Indeed too much praise for the perfection of the entire series of entertainments cannot be accorded the Chairman and his committee, who not only followed out various suggestions made by the membership, but so elaborated them as to make the best possible provision for the pleasure of the voyagers. The friendships formed on such a journey, which must remain a source of satisfaction long after the details of the trip are forgotten, and which contribute so much to the welding together of the Society's membership, were, it is needless to say, a feature the importance of which cannot be measured. The greatest regret was expressed on every side at the unavoidable absence of President and Mrs. George Westinghouse. The entire trip was remarkable for fine weather and smoothness and was made comfortable and pleasurable to all by the excellent service.

At six o'clock Sunday evening, July 24, the Celtic entered the River Mersey, where she was met by the White Star tender Magnetic, bringing a deputation from the Lord Mayor of Liverpool and from the Institution of Mechanical Engineers. The party consisted of Deputy Lord Mayor, Henry Lea, Esq., a member of the Council of the Institution and formerly Lord Mayor of Liverpool; J. A. F. Aspinall, President of the Institution; Prof. W. H. Watkinson of Liverpool University, a member of the Institution; Edgar Worthington, Secretary of the Institution; and several others, all of whom brought to the American Society the official greetings of the city of Liverpool and of the British organization. In the absence of President Westinghouse, Vice-President Goss and other officers of the Society received the guests in the saloon of the Celtic. The Deputy Lord Mayor in a cordial speech regretted the unavoidable absence of the Lord Mayor of Liverpool, on whose behalf he bade them welcome as brethren both in blood relationship and in professional interests. America, he had found in his own visits to that country, a delightful place inhabited by delightful people, and he hoped that England might prove both enjoyable and profitable to the visitors.

Mr. Aspinall then tendered the welcome of the English Institution, which had so long been anticipating the visit of its American brothers. Great Britain, he said, was a somewhat acquisitive nation and it was hoped that the visitors would leave behind them a great volume of good mechanical ideas, and that they would find the visits to British works of as great interest and value as he had found those which he had made in America. In the United States, he understood, university work for engineers was ahead of that in Great Britain, and the graduates from these colleges were so numerous and energetic that they were spreading themselves over the British colonies.

Professor Watkinson followed with a few remarks regarding American colleges, describing his recent visit and the kindly treatment he had received, and expressing himself as deeply impressed by the magnificent equipment and the enormous research work being done. He concluded with a cordial welcome from the engineering department of Liverpool University.

Edgar Worthington, a friend of long standing of the American Society, was also called upon for a few remarks. Mr. Fothergill, representing the management of the White Star Line, made a short speech placing the facilities of his company at the disposal of the travelers upon arrival.

These hearty greetings were acknowledged by Vice-President Goss, who expressed the gratification of himself and of his American friends, and their keen appreciation of the coming events.

After the welcoming delegation had departed, the Celtic was towed to her dock to remain over night, the party landing in Liverpool the next morning and, after the necessary formalities of the customs, proceeding at once to the Lime Street Station where special dining coaches waited to convey them to Birmingham. President Aspinall of the English society, together with Mrs. Aspinall and their daughters, and also Fred. W. Taylor, Past-President of the Society, and Mrs. Taylor who had reached England some days earlier, were on board the train to greet the party.

At Birmingham, Messrs. Howard Heaton and Fred. M. Lea, Honorary Secretaries of the Local Committee, received the party upon their arrival and escorted them to motor omnibuses which conveyed them to their respective hotels. So thoroughly had the Committee on Transportation, Charles Whiting Baker and the Secretary, done its work that not only had hotel accommodations for each individual been arranged in Birmingham and London, but no one from the time of the departure of the Celtic to the close of the meeting in London, was obliged to concern himself in the least regarding the disposal of baggage.

On Monday evening President Aspinall tendered a dinner at the Queen's Hotel to the Past-Presidents and Council of the American Society, to which were also invited the Council and Past-Presidents of the Institution. The Lord Mayor of Birmingham, Alderman W. H. Bowater, was the guest of honor. There were also present, Dean W. F. M. Goss, Sir William H. White, Sir Oliver J. Lodge, Charles Whiting Baker, Arthur Keen, Ambrose Swasey, Sir Gerard A. Muntz, Bart., James Mapes Dodge, William H. Maw, Jesse M. Smith, Sir George Kenrick, Oberlin Smith, Edward P. Martin, Prof. F. R. Hutton, J. Hartley Wicksteed, Prof. R. C. Carpenter, Joseph S. Taylor, Walter Pitt, J. C. Vaudrey, Henry Lea, Henry L. Gantt, H. A. Ivatt, Robert Matthews, H. Graham Harris, Worcester R. Warner, H. F. Donaldson, William H. Allen, Howard Heaton, Alderman Sir Hallewell Rogers, John R. Freeman, Prof. W. Cawthorne Unwin, Arthur T. Keen, Edgar Worthington, James Hartness, Hon. William H. Wiley, Loughnan Pendred, Mark H. Robinson, Fred. M. Lee, E. B. Ellington, Frederick W. Taylor, F. Dudley Docker, George M. Brill, Michael Longridge, George Tangye, Edward Hopinkson, George Robert Jebb, Capt. H. Riall Sankey Reginald K. Morcom, Godfrey Nettlefold, Dr. H. S. Hele-Shaw, Eric M. Carter, and the Secretary. Toasts were given to the King, the President of the United States, and to the Guests. Respecting the latter, Mr. Aspinall spoke of his gratification at the welcome which the city of Birmingham had accorded to the American visitors and of the great regret felt by all at the absence of Mr. Westinghouse, to whose coming all had looked forward, some in appreciation of him as a friend and a splendid host, and all in admiration of him as an engineer known from one end of the world to another. It was most appropriate that the societies should gather in Birmingham where the Institution of Mechanical Engineers was founded in 1847, under the leadership of its first president, George Stephenson, in a hotel of the same name, if not the very building in which this dinner was now held. Referring to the Joint Meeting now in progress, it had for an object, he said, not only the study of the work of our brother engineers, but the widening of acquaintance with one another.

Dr. Goss, as acting President, responded to this toast on behalf of the Society, and brief remarks were also made by Ambrose Swasey and other members.

TUESDAY, JULY 26

The Joint Meeting was formally opened on Tuesday, July 26, at 10 o'clock, in the Lecture Hall of the Birmingham and Midland Institute. The officers of the two societies who had assembled in the Institute Board Room previous to the meeting, entered the hall in a body at the beginning of the session, and took their assigned seats on the platform. The American Society was represented by Dr. W. F. M. Goss, James M. Dodge, John R. Freeman, F. R. Hutton, Jesse M. Smith, Oberlin Smith, Ambrose Swasey, F. W. Taylor, Worcester R. Warner, Charles Whiting Baker, E. D. Meier, Henry L. Gantt, James Hartness, Wm. H. Wiley, Willis E. Hall, and the Secretary. The Lord Mayor of Birmingham, Alderman W. H. Bowater, heartily welcomed the members to the city on behalf of the Reception Committee, whose chairman, Mr. Neville Chamberlain, was prevented by a slight accident from being present, and expressed the hope that the American visitors would feel when the time came for their departure that they had been treated not as strangers but as members of the same brotherhood. It was very fitting that Birmingham, the birthplace of the English Institution, considered the very center of mechanical engineering, should have been selected for so important a gathering as the present meeting. Some people did not think it a very beautiful city, but its own inhabitants were delighted with the darkness of the atmosphere and the ever-present smoke because the more plentiful the smoke the greater the volume of business in the workshop.

The Lord Mayor was followed by Mr. George Tangye, Vice-Chairman of the Reception Committee, who as custodian of the Boulton and Watt relics, offered to the Society a framed letter written by James Watt in 1777, as a memento of their visit to Birmingham. President Aspinall of the Institution in expressing his own appreciation of this gift by Mr. Tangye to the American Society referred to the close connection between the two nations as illustrated by the fact that Boulton and Watt sold to Robert Fulton his first engine. Birmingham had thus played its part in engineering work on both sides of the Atlantic. Another of its citizens, James Wyatt, invented the first cotton-spinning machine in 1741 and the first hanks of cotton produced by it might be viewed at any time in the city museum. Engineers recognized, he said, how much they owed to Birmingham and how much the city had done and was doing, not only in scientific advancement by means of their great university, but by the hard-headed constructive knowledge and ability of the people who fought to keep in British hands by the peaceful weapons of commercial conquest a fair share of the world's trade.

Dr. W. F. M. Goss expressed the hearty thanks of the American Society for the welcome accorded them and to Mr. George Tangye for his generous gift. This was the third official visit of the Society to England and previous experience had taught the members how great a privilege it was to be the guests of the Institution. Entering England with a recognition of how many practices of the profession had their beginning here, they were already in full enjoyment of everything found in the country, from the green of the trees and meadows to the permanency and beauty which characterized so many of the engineering structures. Under present-day conditions the engineer had become the world's great civilizer and in the transforming process in which men had been given new occupations and the world of their fathers replaced by a new world, the engineers of England and America had had a large part. National boundaries no longer affected them for, thanks to the English shipbuilders, the ocean between them had become an easy means of communication. The spirit of the two organizations, if not the organizations themselves, might be federated, and to such a result this Joint Meeting was sure to prove a contributing factor. Mr. Tangye's generous gift had quite taken them by surprise and they would not forget the giver in their enjoyment of the new possession.

The inscription on the frame of the memorial was then read:

PRESENTED TO THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS BY GEORGE TANGYE AT THE JOINT SUMMER MEETING AT BIRMINGHAM IN JULY, 1910. Dr. Goss added that the letter was both written and signed by James Watt, and was very legible and well preserved in every respect. A photograph of the letter, showing the two sides, is given herewith.

Mr. Aspinall then took the chair and at his request a telegram of regret was sent to Mr. Westinghouse.

After the transaction of some routine business the following papers were read and jointly discussed, the chair being alternately occupied by Mr. Aspinall and Dr. Goss on this and succeeding days: English Running-Shed Practice, by Cecil W. Paget, Member I. Mech.E., General Superintendent, Midland Railway, Derby; Handling Locomotives at Terminals, Frederic M. Whyte, Vice-President Am.Soc.M.E., General Mechanical Engineer, New York Central Lines, New York; Engine-House Practice, F. H. Clark, Mem.Am.Soc.M.E., Chicago, Ill.; American Locomotive Terminals, William Forsyth, Mem.Am. Soc.M.E., Railway Age Gazette, Chicago, Ill.; and Handling Engines, by H. H. Vaughan, Member I. Mech.E. and Am.Soc.M.E., Canadian Pacific Railway, Montreal, Can. The discussers were George Hughes, James M. Dodge, Henry Fowler, Henry L. Gantt, Arthur D. Jones, J. E. Sague, F. H. Clark, Cecil W. Paget, William Forsyth, F. M. Whyte and H. H. Vaughan.

Tuesday Afternoon and Evening

After luncheon, which through the courtesy of the Lord Mayor, was served in the Town Hall, the visitors scattered to enjoy the various trips to places of professional and historical interest in and about Birmingham, arranged by the local Reception Committee for both Tuesday and Wednesday afternoons. One of these was a trip to Dudley Port, Tipton, where inspection was made of the works of the South Staffordshire Mond Gas Company, under the guidance of the Managing Director, Edmund Howe, Esq., Member I.Mech.E. This company distributes gas for power and heating purposes over an area of about 123 sq. mi., in what may be termed the industrial heart of England. The plant comprises eight producers, each capable of gasifying 20 tons of fuel per day and generating sufficient gas to drive gas-engines of 2000 h.p. continuously. Here also the testing station of the Pump and Power Company was visited, which contains four Humphrey pumps of various types, the largest of which is 4-

cycle, delivering 250,000 gal. per hr. to a height of 35 ft. H. A. Humphrey, Esq., Managing Director, Member I. Mech.E., conducted the party.

Another excursion was that made to the works of the Austin Motor Company at Northfield, under the guidance of H. Austin, Esq., Governing Director, where the range of models manufactured comprises the 4-cylinder engine of the 25 to 30 h.p. type; a smaller model of 18 to 24 h.p.; a 15-h.p. 4-cylinder model in two forms, one having the engine in front and with narrowed frame used for taxicab work, and the other the engine under the driver's seat, used for landaulet or coupé carriages, or light delivery vans to carry loads up to 15 cwt.; a 7-h.p. single-cylinder; a 50-h.p. 6-cylinder; and an 18 to 24-h.p. 4-cylinder of a special type fitted with detachable wire wheels. The works of the company occupy over six acres, one building being devoted to the machine shops, and the other departments being the grinding section, hardening shop, power house, engine test-house, plating and polishing sections, erecting shop, copper and tinsmith's shop, chassis test-house, wheel building shop, finishing shop, pattern-maker's shop, carriage building shop. The restaurant of the company, where the guests had tea, is shown herewith.

A third party, conducted by the Managing Director, Percy Wheeler, Esq., Member I.Mech.E., visited the Metropolitan Amalgamated Railway Carriage and Wagon Company at Saltley, which covers 20 acres and comprises a smith, smithy power house, steel under-frame shop, machine shop, power house, boiler house, foundry, saw mill, gantry, wagon building shop, car body shop and paint shop. These works are lighted by electricity generated on the grounds and employ about 3000 men.

The Frankley Filter Beds to which a trip was also arranged, are situated near Northfield, and form a portion of the Elan Supply Works designed to furnish eventually 72,000,000 gal. per day. Points of especial interest are the reservoir, filter washing, pure water reservoirs, pumping station, and the mains and meters. The resident engineer, F. N. Macaulay, Esq., acted as escort. On all of these trips tea was served at the works, usually in the employees' mess room, commonly found in English workshops.

An excursion to Stratford-upon-Avon included visits to Shakespeare's birthplace, the Church, the Memorial Theatre, Anne Hathaway's Cottage, and other points of interest. Tea was served at the Shakespeare Hotel. Many of our party were interested in the fact that The Piper, a play written by one of our own country-women, the wife of one of our members, Josephine Preston Peabody (Mrs. L. S. Marks), of Cambridge, was to be produced for the first time on Wednesday evening at the Memorial Theatre, having been awarded the £300 prize in a world's contest. A number of the members of the Society were present at this initial performance which received much favorable criticism.

A trip was also made to the historic town of Worcester, "The Faithful City," where at the Guildhall the Mayor, Hon. Alfred Percy Allsopp, and the Corporation of Worcester, welcomed the party. At the Cathedral, on the eastern bank of the Severn, the Dean, the Very Reverend Dr. W. Moore Ede, gave a brief historical address, tracing the growth of the group of buildings from their beginning as a small Benedictine Monastery in 680 A.D., through the building period fostered by the Normans in the eleventh century, their vicissitudes under Henry VIII and again under Cromwell, to their final restoration in 1874. This great cathedral of the Western Midlands is simple in plan, and while the restoration has of necessity removed much of the "atmosphere" of antiquity so dear to the American visitor, the interior has a wonderful perfection of design, and gives proof of the most reverent care.

The party also visited the Worcester Porcelain Works which were founded in 1751 by Dr. John Wall, a distinguished physician and artist who succeeded in producing one of the most beautiful of the porcelains and to whom in 1788 King George III granted a patent which gave to Worcester the first royal porcelain works in England; as well as the quaint Hospital of St. Wulstan, commonly called the Commandery, which dates back to the 11th century. The entire place is rich in historical associations, intimately connected with the Civil War, and is full of carvings, furniture and objects of art.

Some of the party also visited Stoneleigh Park where after a view of the ruins of the old Cistercian Abbey built in the 16th century the party proceeded to Kenilworth, seeing the Castle and having tea at the Abbey or Kings Arms Hotels.

All of these trips were arranged by the Committee with the greatest care and forethought for the welfare and pleasure of the visitors, special trains or motor buses as well as guides being supplied in every case, and provision being made for both luncheon and tea. On the technical excursions these were furnished through the courtesy of the companies.

Birmingham itself contains so many places of professional interest that many of the guests took advantage of the opportunity to inspect some of the engineering works located in the city, among the most prominent of which are James Archdale and Co., Manchester Works; Aston Manor Corporation Electric Power Station; Birmingham Corporation Electric Supply Station; James Cartland and Son; Elkington and Co.; General Electrical Co., Witton Works; Joseph Gillott and Sons, Metallic Pen Manufactory; National Telephone Co.'s Exchanges; F. and C. Osler; Taylor and Challen, Derwent Works; H. W. Ward and Co.; Webley and Scott; E. G. Wrigley and Co., Foundry Lane Works.

The older part of the city is crowded with these workshops and warehouses, but the modern part is well built and full of fine specimens of architecture. Most of its municipal undertakings date back to 1875 when Mr. Joseph Chamberlain, then its Mayor, inaugurated the new era.

A Ladies' Committee, consisting of the Lady Mayoress, Mrs. W. H. Bowater, Chairman, Mrs. Horatio Lane, Honorary Secretary, and Mesdames C. G. Beale, George Beech, Eric M. Carter, James Chatwin, George Vonaty, A. E. Cutler, David Davis, H. Ashton Hill, E. C. Keay, E. Antony Lees, Sheffield, J. D. Steven, William Tangye, J. C. Vaudrey and Miss Vaudrey, W. E. Warden, and Philip J. Worsley, on Tuesday and Wednesday mornings escorted the visiting ladies to various points of interest in the locality, providing special omnibuses for the trip.

Many of the members also accepted Mr. George Tangye's kind invitation to visit the Watt room in Heathfield Hall which, formerly the home of James Watt, has been occupied by Mr. Tangye for the past 25 years. The room is in every detail of its contents just as Watt left it, and all who appreciated the splendid genius of this early engineer could not but view with reverence the hundred-year-old stove, containing the ashes of the last fire burnt in it while Watt lived; the chest of drawers full of odd bits of metal, scraps of wood, mathematical instruments and the like; the first copying press, one of Watt's inventions, now standing with the dust of years upon it; his lathe with its lamp and tools untouched and the leather apron hung up where he left it; and many perfected or half-perfected processes or machines, all showing so clearly his instinct and passion for invention. The curator of these relics, which Mr. Tangye long ago presented to the city of Birmingham, made the visit doubly interesting by his personal guidance and explanation. A copy of the portrait of James Watt, painted by Sir William Beechy, which hangs in the dining room at Heathfield, is here reproduced through the kindness of Mr. Tangye.

The brilliant garden fête given by the Birmingham Reception Committee on Tuesday evening in the Botanical Gardens at Edgbaston, and attended by more than 5000 guests, was remarkable for the lavishness of its hospitality as well as for the splendor of the entertainment afforded and the scenic effect produced in the grounds. On every hand strings of miniature lamps and Japanese lanterns cast a radiant glow upon the paths and the awnings of the conservatories and lawn. The Lord Mayor and Lady Mayoress, Alderman and Mrs. Bowater, Alderman Sir G. H. Kenrick, Sir Oliver J. Lodge, Mr. Henry Lea and Mr. George Tangye, received the members and friends in the Floral Hall which was especially decorated for the occasion. Music was furnished by the band of the Royal Marines of Portsmouth and during the evening a series of fine fireworks was displayed, including a set piece showing the British and American flags crossed in the air. An elaborate luncheon was served in the tents and the American guests were conveyed to and from their hotels by special motor omnibuses.

WEDNESDAY, JULY 27

The meetings in the Midland Institute were resumed on Wednesday morning at 10 o'clock, when the following cablegram was read from President Westinghouse in reply to that of Mr. Aspinall sent on Tuesday: "Express my deep appreciation to Lord Mayor, Aspinall, Goss and Members both associations for their expressions of regret because of my absence and for their good wishes. I have the highest hope that the Joint Meeting will be of permanent value in further cementing the relations between the societies, and in promoting coöperation between the engineers of the two countries."

The following papers were then presented and discussed: High-Speed Tools and Machines to Fit Them, by H. I. Brackenbury, Member I.Mech.E., Elswick Works, Sir W. G. Armstrong, Whitworth & Co., Newcastle-on-Tyne; Rapid Production in Machine Work; Abstract of Data Collected by The American Society of Mechanical Engineers, read by John Calder, Mem.Am.Soc.M.E., Manager, Remington Typewriter Works, Ilion, N. Y.; Data on Manufacturing Methods with Machine Tools, by Luther D. Burlingame, Mem.Am.Soc.M.E., Chief Draftsman, Brown & Sharpe Co., Providence, R. I.; and Development of High-Speed Drilling Machines, by L. P. Alford, Mem.Am.Soc.M.E., Engineering Editor American Machinist, New York. They were discussed by J. Hartley

Wicksteed, William Lodge, Dempster Smith, Frank B. Gilbreth, H. I. Brackenbury, Daniel Adamson, George Addy, Alexander Taylor, W. F. M. Goss and John A. F. Aspinall.

Papers on Tooth Gearing, by J. D. Steven, Associate Member I. Mech.E., Messrs. E. G. Wrigley & Co., Soho, Birmingham; and on Interchangeable Involute Gearing, by Wilfred Lewis, Mem.Am.Soc. M.E., President Tabor Manufacturing Company, Philadelphia, and Chairman of the Committee on Standards for Involute Gears, were also read in abstract, and were discussed by P. V. Vernon, C. R. Gabriel, Luther D. Burlingame, Daniel Adamson, Thomas Humpage, R. M. Neilson, J. R. Williams, and Wilfred Lewis.

President Aspinall moved that the following resolutions of thanks to their hosts and to the many people in and around Birmingham for the great hospitality which they had extended to the members of the two organizations be accepted:

That the best thanks of the Members of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers in this meeting assembled be given:

To the Right Hon. the Lord Mayor of Birmingham, Alderman W. H. Bowater, for his welcome of the President, Council, and Members of the two institutions to the city of Birmingham; for his and the Lady Mayoress's kind invitation to a Reception in the Council House; also for his courteously lending the Town Hall for the purposes of the luncheons.

To the Ladies' Committee for so kindly entertaining the lady visitors.

To the Chairman of the Reception Committee, the Lord Mayor; the Vice-Chairmen, Alderman Sir George H. Kenrick, Mr. Henry Lea, Sir Oliver J. Lodge, D.Sc., Ll. D., F.R.S., Mr. George Tangye; the Hon. Treasurer, Mr. Alexander Fyshe; and the members of the Birmingham Reception Committee, for the attractive programme they have prepared for the meeting and excursions, and for their hospitable entertainment of the members at the garden fête.

To the Chairman and Directors of the South Staffordshire Mond Gas (Power and Heating Co.), the Pump and Power Co., the Austin Motor Co., the Metropolitan Amalgamated Railway Carriage and Wagon Co., Mr. F. W. Macaulay, Messrs. E. G. Wrigley and Co., Messrs. Mitchells and Butlers, Messrs. Walter Somers and Co., and the numerous proprietors of places of engineering interest in Birmingham, Coventry, Rugby, and neighbourhood, for their kindness in throwing open their Works for the visits of members and for hospitalities; also to the Birmingham and Midland Institute, the Birmingham Association of Mechanical Engineers, and various clubs and the Birmingham Exchange for the extension of hospitable facilities.

To the Right Hon. the Earl of Warwick for inviting the members and ladies to visit Warwick Castle.

To the Right Hon. the Earl of Clarendon for permitting the members and ladies to visit Kenilworth Castle.

To the Right Hon. Lord Leigh for permitting the members and ladies to visit Stoneleigh Abbey.

To the Mayor and Corporation of Worcester for their civic welcome; to the Very Rev. Dean of Worcester for permission to visit the Cathedral; to the Worcester Royal Porcelain Co., for permission to visit their works; and to Mr. Joseph Littlebury for his reception and address at "Ye Antient Commandery"; and to Mr. C. J. Seaman for arranging the visit to Worcester.

To the Very Rev. Dean of Lichfield for permission to visit the Cathedral; to Councillor Charles Harradine, chief verger, for conducting the members and ladies over the Cathedral; to Councillor William A. Wood, Chairman of the Johnson Birthplace Committee, for conducting them over Dr. Johnson's house; and to Alderman Herbert M. Morgan, for inviting them to the Old Grammar School house, Lichfield.

To the Council of the University of Birmingham for the reception and entertainment of the members and ladies at the new buildings.

To Mr. George Tangye for his invitation to visit the Watt room at his residence.

To Messrs. Alfred Herbert, the Daimler Motor Co., and to the Wolseley Tool and Motor Car Co., for inviting the members to visit their works, and for their kindness in entertaining the members at luncheon.

To the Honorary Local Secretaries, Mr. Fred. M. Lea and Mr. Howard Heaton, for planning numerous visits to places of interest in Birmingham and neighbourhood, and for the admirable arrangements which their forethought and energy have provided during the meeting.

To the London and North Western, the Great Western, the Midland, and other railway companies of Great Britain for special traveling facilities connected with the meeting.

The Secretaries of the two societies were instructed to transmit these resolutions to the various corporations and individuals and Professor Hutton voiced their support by the American members. The resolutions were carried by acclamation.

Wednesday Afternoon and Evening

Wednesday afternoon, after luncheon again served in the the Town Hall, was also spent in sightseeing. Many availed themselves of the opportunity to visit the new buildings of the University of Birmingham, opened in July 1909 by the late King Edward, which is splendidly equipped for the study of chemistry, physics and mechanical, civil and electrical engineering. No small part of the formation of this, the leading technical college in Great Britain, was due to the genius and untiring efforts of Mr. Joseph Chamberlain, who in 1898 in a public announcement planted the seed of which this great group of buildings is now the harvest. It was at the suggestion of an

American citizen, Mr. Andrew Carnegie, by whom a donation to the fund was made, that a committee was sent to investigate the work done in America, as a result of which the American system of engineering was introduced into the University by its Council. Sir Oliver J. Lodge, a man of broad sympathies and of world-wide scientific reputation has as its Principal done much by his remarkable personality to realize Mr. Chamberlain's ideal that the University "be not only a school of general culture but practically assist the prosperity and welfare of the district by attention given to teaching science in connection with its application to local industries and manufacturies." On arrival at the University the party were received on the steps by Sir Oliver J. Lodge and in the rotunda by the Vice-Chancellor, Alderman C. G. Beale the Pro-Vice-Chancellor, Alderman F. C. Clayton; the Vice-Principal, Prof. R. S. Heath, and the Professors. The buildings and grounds were fully inspected and after tea served on invitation of the Council of the University in the Great Hall, a magnificent edifice in which all public ceremonies are held, the guests returned to Birmingham in the special motor omnibuses provided for the trip.

A trip was made by others to the brewery of Messrs. Mitchells and Butlers, at Cape Hill, Smethwick, under the guidance of the deputy Chairman, W. Walter Bulter. The malt used in the manufacture of beer is produced on the premises, and the beer when finally manufactured is run into casks by a special apparatus which ensures absolute cleanliness. A display of the company's Volunteer Fire Brigade, which has won several prizes, was given in the presence of the visitors. The directors provide for the recreation of their employees in bowling greens, cricket grounds and a football field, as well as rooms for ambulance practice, lectures, etc. Conveyances and refreshments were offered to the sightseers through the courtesy of the company.

The reception given by the Lord Mayor and Lady Mayoress in the Council House on Wednesday evening, was largely attended and much appreciation expressed of the beauty of the floral decorations and the excellence of the music. The Council House contains a large reception room and art gallery besides the Council Chambers, and all of these were thrown open to the guests. Refreshments were served in the gallery at the conclusion of the reception, and the guests conveyed to their hotels in special motor omnibuses. The Lord Mayor and Lady Mayoress, who personally attended the various functions, not only contributed much to the occasion by their presence but very effectively emphasized the cordiality of our reception.

THURSDAY, JULY 28

Both organizations bade farewell to Birmingham on Thursday morning with many expressions of appreciation of their delightful sojourn and regret at leaving the many friends who had made them welcome. The entire day was devoted to sightseeing, all the plans, which provided for four alternative excursions, having as an objective point the arrival of the members in London that same evening, where on Friday and Saturday the final sessions of the Joint Meeting were to be held.

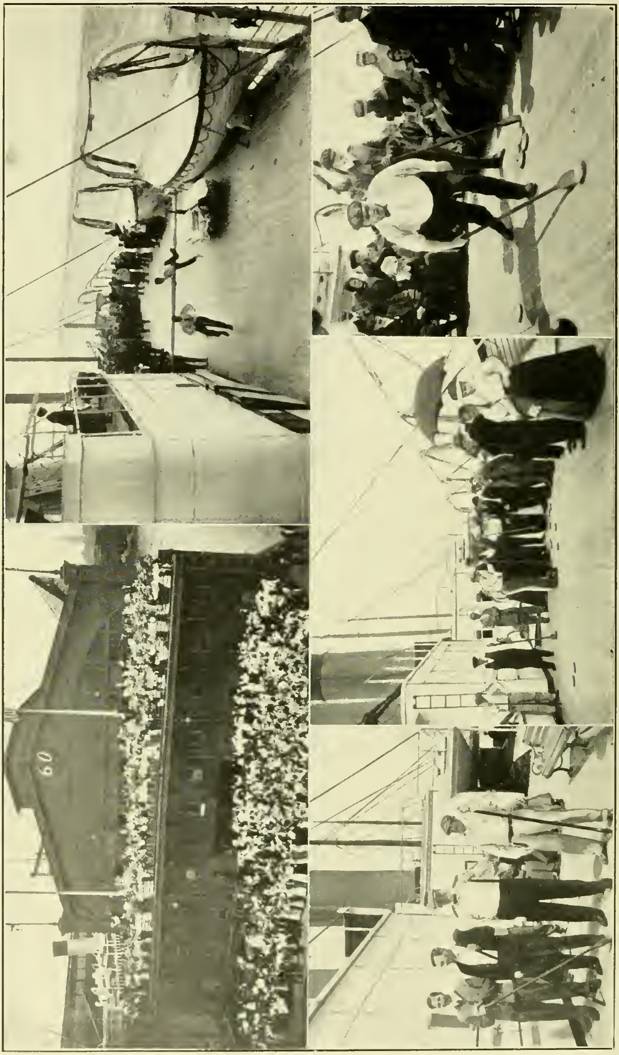
The guests on one of these trips visited Coventry where the Edgwick Works and Foundry and also the Head Works of Messrs. Albert Herbert were inspected under the personal guidance of Mr. Herbert himself, Member of the Institution. This firm manufactures horizontal and vertical milling machines, capstan lathes, automatic screw and turning-machines, light drilling-machines and universal grinding machines. Piece work is employed throughout, a separate price being given for each operation. On Mr. Herbert's invitation the party took lunch in the new building of the company.

Some of the party on arrival in Coventry went instead to the works of the Daimler Motor Company where they were escorted through the buildings by Percy Martin, Esq., Member of the Institution, and were interested in viewing the thirteen different trades brought into operation at these works, namely, machining, fitting, engine-testing, erecting, copper-smithing, electro-plating, etc., the whole occupying in shops alone 8½ acres of floor-space. The company had provided luncheon for the party which was served at the works.

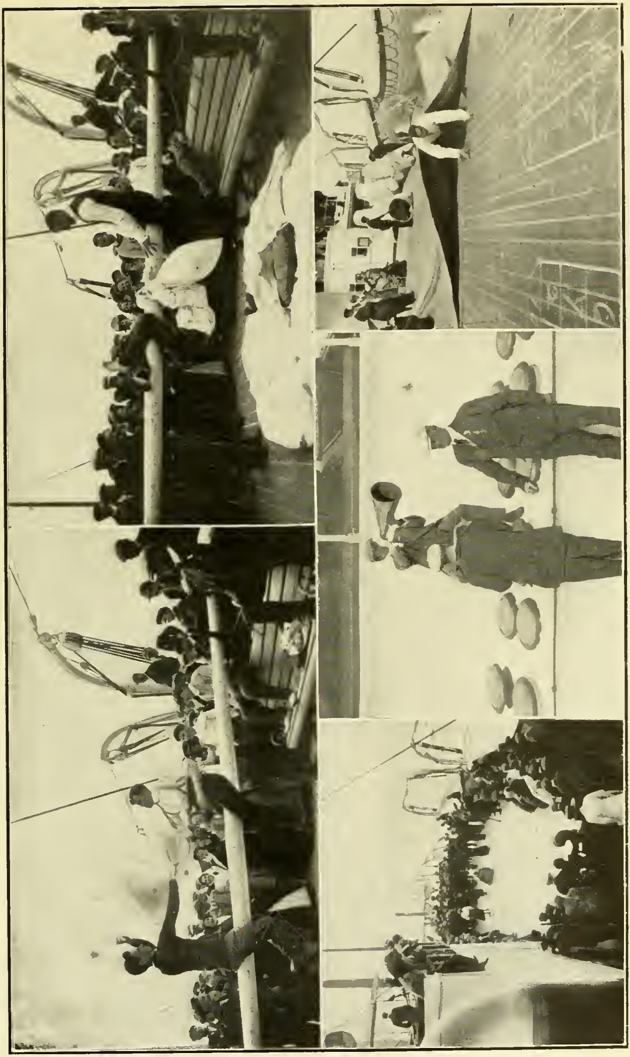
From Coventry the party proceeded to Rugby, where one group visited the works of Messrs. Willans and Robinson, under the guidance of the general manager, James C. Peach, Esq., Member of the Institution, the principal output of these works being steam turbines, steam and oil engines, condensing plants and pumps. Others inspected the works of the British Thomson-Houston Company, with the chief engineer, H. N. Sporborg, Esq., as escort. This company manufactures electrical apparatus and Curtis turbines for traction, lighting and power purposes.

S.S. Celtic, White Star Line, the Official Ship

Capt. A. E. S. Hambelton, Commanding S.S. Celtic



Scene on the Dock at Departure and Views on Board Ship

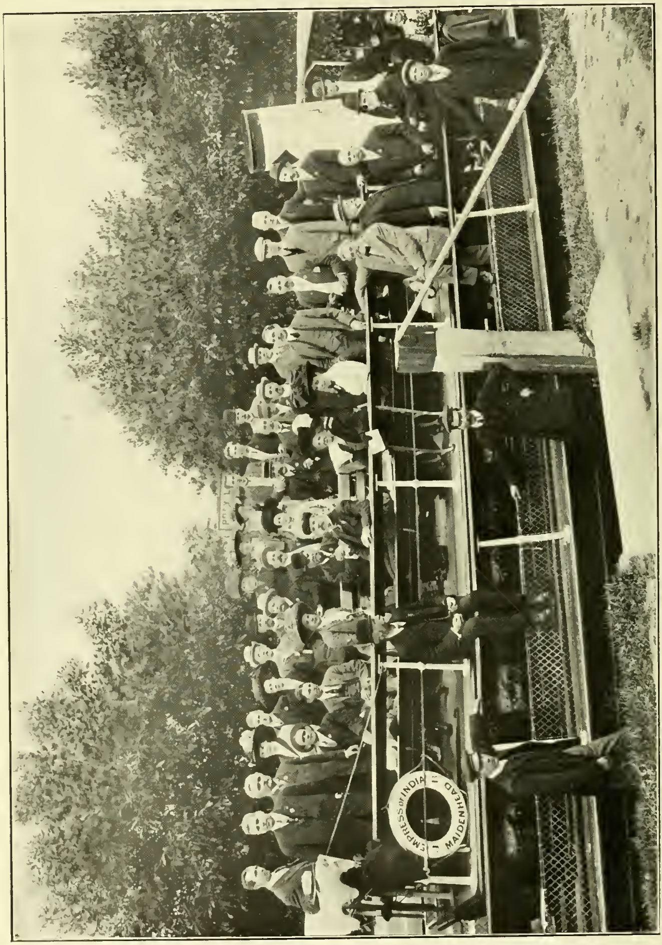


THE SPORTS ON BOARD THE CELTIC

MIDLAND INSTITUTE, BIRMINGHAM, AND MOTOR BUSES WHICH CONVEYED MEMBERS AND GUESTS TO AND FROM THEIR HOTELS

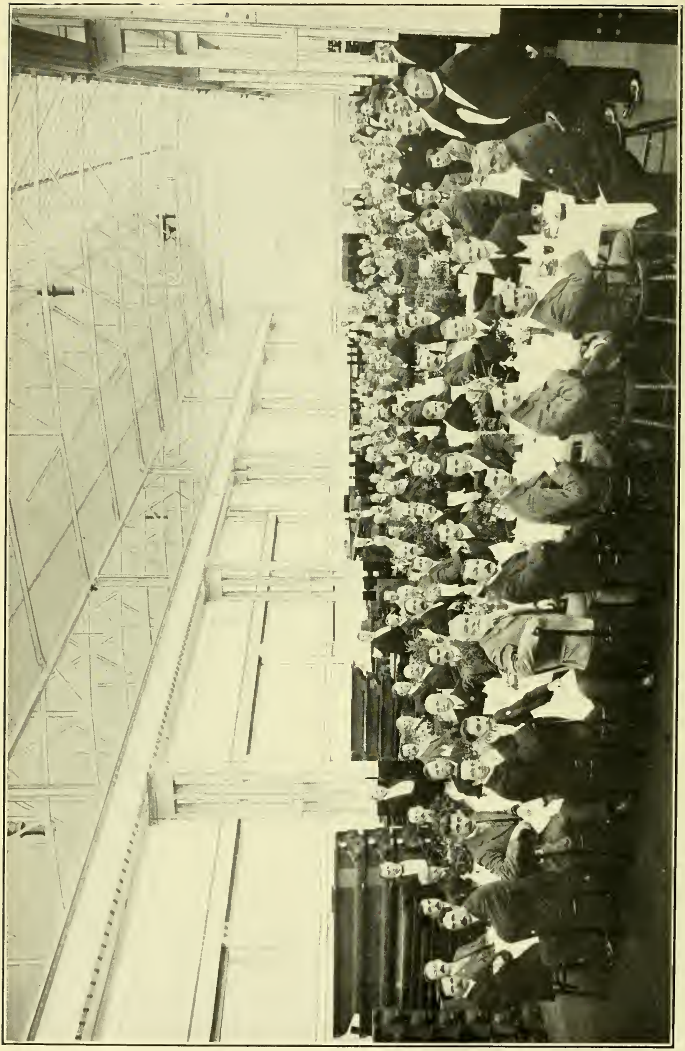
THE WATT HOUSE AT HEATHFIELD

Group of Members and Guests Entertained by Mr. Tangye



On the Thames River, on Board the "Empress of India"

On the Thames River, on Board "His Majesty"



Visit to the Works of Alfred Herbert, Ltd., Coventry;
The Employees' Dining Room where the Party had Tea

Another trip took the sightseers to Lichfield, stopping at Hammerwich en route, where under the guidance of the engineer, H. Ashton Hill, Esq., they visited the Pipe Hill Pumping Station of the South Staffordshire Water Works Company, which supplies a population of nearly three-quarters of a million. At Lichfield they were shown through the finely-proportioned three-spired cathedral one of the best existing types of the fourteenth century English church, by the chief verger, Councillor Charles Harradine. This edifice is constructed of red sandstone and the western façade, the principal entrance, has a wonderful richness of decoration. In this same town also, Dr. Samuel Johnson was born and the party were fortunate in viewing his birthplace under the guidance of the Chairman of the Johnson Birthplace Committee, Councillor William A. Wood. In the middle of St. Mary's Square, facing his father's house, is a colossal statute of of the doctor himself, which looks down upon the spectator from a pedestal ten or twelve feet high. Alderman Herbert M. Morgan, ex-Mayor of Lichfield, took the visitors through the Old Grammar School, where Johnson, Addison, Elias Ashmole, Garrick and Darwin once sat upon the rude benches and no doubt spent many uncomfortable hours.

Other members of the Society visited the works of the Wolseley Tool and Motor Car Company at Adderly Park, about two miles from the centre of Birmingham, which devotes exclusive attention to the manufacture of motor-cars and petrol engines for marine, aeroplane and various purposes, and is equipped with high-class machine tools.

The rest of the travelers made a trip to Kenilworth, Warwick and Stratford-upon-Avon, one group proceeding first to Kenilworth, thence to Guy's Cliff and Warwick, and concluding with a visit to Stratford; and the other going first to Stratford and from there to Warwick and Kenilworth, the two parties passing each other en route. In one case luncheon was procured at Warwick, and in the other at Stratford, in the old Red Horse Hotel which an American finds it impossible not to associate with our own Washington Irving.

At Kenilworth the party viewed the magnificent ruins of the old castle, so full of memories of the days of Elizabeth and of her courtier, the Earl of Leicester. The picturesque Guy's Cliff, which contains the cave in which Guy, first Earl of Warwick, is fabled to have passed his latter days and to have been buried, formed a fitting introduction to the gray towers of Warwick which King

Cymbeline is said to have founded at the beginning of the Christian era. The river Avon, which flows before the castle, so perfectly reflects it in its depths that Hawthorne's fancy with regard to the reality of the mirrored image and the unreality of the upper structure seems amply justified. Through the courtesy of the Earl of Warwick the castle with its many historic relics and architectural beauties was thrown open to the visitors.

At Stratford-upon-Avon, now a successful place of business and often for that reason a disappointment to the visitor because of its "newness," the party visited Shakespeare's birthplace where the beholder must always marvel at the humble surroundings of the man whose splendid imaginings have so peopled our world; the church in which stands his tomb engraved with the famous "curse"; Anne Hathway's Cottage of much the same rude order as Shakespeare's house; and the Memorial Theatre, a more modern structure. On all of these excursions as on the previous day, the amplest provision and care had been made for the conveyance and refreshment of the travelers.

More than 800 guests, even after this strenuous day, assembled in the evening at the delightful Conversazione given in the rooms of the Institution. This building, which has been erected since the former visit of the American members to England in 1889, was much admired by all for the beauty of its architecture and decorations and for its fine site overlooking the waters of St. James Park. President and Mrs. Aspinall received the guests in the large hall which is decorated with Hungarian oak panellings, surmounted by red walls and enriched ceilings. During the evening, music was rendered here and in the library by the band of the Royal Artillery and by several fine vocalists. A short lecture illustrated by lantern slides was given by Dr. H. S. Hele-Shaw, on Stream Line Experiments Illustrating Aeroplane Stability. Refreshments were served in the Marble Room.

FRIDAY, JULY 29

The concluding professional session of the Joint Meeting was held on Friday, in the Institution House of the Civil Engineers, which is diagonally opposite the headquarters of the Mechanical Engineers. On account of the fatigue of the previous day the attendance was small, but those who were present were repaid by the opportunity of meeting in the dignified rooms of the Institution and of participating in the discussion of especially able papers on Electric Traction. The societies were welcomed by Mr. Alexander Siemens, Senior Vice-President, who expressed the Institution's great pleasure in thus offering to the Joint Meeting the use of their theatre. President Aspinall responded and in expressing his thanks spoke of the improbability that another such gathering would be held in the historic building, because of the early occupation by the Institution of their new home. Dr. Goss, on behalf of the American members, spoke of the charm such a building had for those from a newer environment and of their appreciation of being able to gain some acquaintance with the Institution.

The following papers were then read in abstract: Electrification of Suburban Railways, by F. W. Carter, of Rugby; The Cost of Electrically-Propelled Suburban Trains, by H. M. Hobart, of London; Economics of Railway Electrification, William Bancroft Potter, Mem.Am.Soc.M.E., Engineer, Railway and Traction Department, General Electric Company, Schenectady, N. Y., presented by H. H. Barnes, Jr., of New York; The Electrification of Trunk Lines, by L. R. Pomeroy, Mem.Am.Soc.M.E., J. G. White, Co., Inc., New York, N. Y.; The Electrification of Railways, by George Westinghouse, President Am.Soc.M.E., Pittsburg, Pa., presented by Charles F. Scott, of Pittsburg. These were discussed by Charles F. Scott, H. F. Parshall, J. Dalziel, Sidney Stone, Edgar Worthington, H. M. Hobart, Angus Sinclair, J. G. Wilson, F. R. Hutton, F. W. Carter, H. H. Barnes, Cary T. Hutchinson, and J. R. Williams.

The following resolutions of thanks were then put to vote and carried by acclamation:

To Dr. and Mrs. Maw and Sir John and Lady Thornycroft for their kind invitations to the members and ladies to attend garden parties.

To The Times for the invitation to visit their printing works.

To the Council of the Institution of Civil Engineers for so kindly placing their lecture hall at the disposal of the members for the purposes of the London meeting.

To His Worship the Mayor of Windsor, Councillor C. F. Dyson, for courteously lending the Guildhall for the purposes of the luncheon in Windsor; also to His Worship and Mr. George Mitchell, Mr. Christopher Sainty and Mr. George Willis for conducting the members and ladies at Windsor.

That the Secretaries of the Institution of Mechanical Engineers and The American Society of Mechanical Engineers be severally instructed to transmit the above resolutions to the various corporations and individuals who have done so much to make the Joint Meeting enjoyable and memorable on both sides of the Atlantic.

Prof. F. R. Hutton made the concluding remarks of the session, speaking at some length of the enjoyment of the American members of the Birmingham and London meetings, and offering the following additional resolutions:

The American Society of Mechanical Engineers, present by invitation at the closing session of the Joint Summer Meeting of 1910 with the Institution of Mechanical Engineers, asks permission to offer for record the following minute, and requests its Acting President to put the resolution to vote:

The American Society of Mechanical Engineers has been enveloped in an atmosphere of courteous, friendly, and devoted attention from the moment that the vessel which carried the official and organized party entered the River Mersey at Liverpool. Beginning with a reception on the steamer, at which the President and Secretary of the Institution officially welcomed the party, in conjunction with representatives of the city and other interests of that progressive corporation, and continuing through the arrangements for comfortable and convenient transportation by train to the place of first meeting; providing on arrival for prompt and satisfactory hotel accommodation, and for organizing, in a masterly way, which extended even to the most minute details for the enjoyment of the visitors on excursions, in affording opportunities to visit works, for transportation, and for motor drives in the historic Midlands of England, the Institution of Mechanical Engineers has placed The American Society of Mechanical Engineers under an obligation which no mere words or resolutions are an adequate medium to discharge. The visitors can only assure the home Society, its President, its Council, its Secretary and its organizing committee that just because they are themselves organizers and doers they are able most thoroughly to appreciate such work well done.

The American Society also appreciates most sincerely the generous purpose which has spared no sacrifice when the desired object of the hosts has had to be met by the ordinary commercial procedure as respects outside parties. Hence the Society moves and seconds the following resolutions:

Resolved, that The American Society of Mechanical Engineers desires, in addition to the resolutions passed in Birmingham thanking those who had put both bodies under a pleasant debt of obligation, to put on record the following special resolutions of thanks:

Resolved, that The American Society thanks the Institution of Mechanical Engineers, its President, Council, Secretary and Committee for their ceaseless, unremitting, and painstaking effort for the pleasure and success of the Joint Meeting of 1910 in Birmingham and London.

Resolved, that this Joint Meeting will be a memory of delight and pleasure for all the Americans who have been privileged to share in it.

Resolved, that The American Society of Mechanical Engineers desires to thank the Birmingham Reception Committee for certain special considerations at their hands, which were extended exclusively to the American members of the Joint Party, and requests the Institution to be the channel for conveying such action of thanks.

Resolved, that The American Society of Mechanical Engineers desires by this action to express for the ladies, who have accompanied the members, something of the appeciation of both members and ladies for the delicate and considerate attention which has made their participation a delight and a possibility. The members feel that international friendships springing from these days of close and enjoyable association are sure to last forward into future happy years.

Resolved, that The American Society of Mechanical Engineers requests the Institution of Mechanical Engineers to incorporate this minute and action as part of its record of the Proceedings of the Joint Summer Meeting of 1910.

These were carried by the rising vote of all the Americans present.

Friday Afternoon and Evening

Two very enjoyable garden parties were given on Friday afternoon, one at the home of Dr. William H. Maw, Esq., Past-President of the Institution, and Mrs. Maw, at Addison Road, Kensington, and the other at Eyot Villa, in Chiswick Mall, the home of Sir John Thornycroft, Member of the Council, and Lady Thornycroft, at both of which the visitors were given a delightful glimpse of English home life.

A number of members also inspected the British Museum, and the Times Office in Printing House Square through which they were conducted by the Chief Engineer, J. P. Bland, Esq., Member I.Mech.E. These offices stand on the site of the building from which the paper was first issued in 1785.

An event to which the American members had looked forward with much delightful anticipation was the banquet given by the Institution on Friday evening in the Connaught Rooms, the largest dining hall in the city of London. After the usual toasts to the Crown had been given, President Aspinall proposed The President of the United States, which was acknowledged by the American Ambassador, the Hon. Whitelaw Reid. Mr. Reid said that he regarded this toast not only as a tribute of high regard for the personal character of the present occupant of the Presidential chair, but also a token of profound respect for the whole country over which he ruled, and that he believed the material conquests which had created and developed the great empire of America, occupying more than one-quarter of the habitable surface of the globe and comprising nearly one-third of its inhabitants, were due to no class more largely than to the mechanical engineers of the two countries represented at this gathering.

Sir William H. White in giving the toast, The American Society of Mechanical Engineers, recalled the fact that it was founded but 30 years ago and yet had now a membership of about 4000. He referred particularly to the long years of service for the Society of Prof. F. R. Hutton, who, he said, had together with the present Secretary, promoted the Society's growth and success, and that by virtue of their ideals for its welfare the American organization was safe in their hands. Professor Hutton in responding said that the present gathering was the culmination of a series of meetings of mechanical engineers on both sides of the Atlantic, and that the profession which they represented underlay the civilization of the Anglo-Saxon race. The American was much at home in the United Kingdom because he and his host had a common ideal.

A toast to Our English Guests, proposed by Edward B. Ellington, Vice-President of the Institution, was acknowledged by Dr. R. T. Glazebrook, Director of the National Physical Laboratory; and the final toast of the evening, The Institution of Mechanical Engineers, given by Dr. W. F. M. Goss, was answered by President Aspinall.

Among the guests of the evening were James M. Dodge, Oberlin Smith, A. H. D. R. Steel-Maitland, M. P., Dr. Worcester, Mr. and Mrs. J. Hartley Wicksteed, Mr. and Mrs. F. W. Taylor, Dr. and Mrs. Wm. Maw, Charles Hawksley, the Lord Mayor and Lady Mayoress of Windsor, E. P. Martin, Mr. and Mrs. Ambrose Swasey, Charles Kirchhoff, J. L. Griffiths, United States Vice-Consul, Mr. and Mrs. John R. Freeman, Sir Gerard and Lady Muntz, Henry Lea, C. F. Scott, Mr. and Mrs. Jesse M. Smith, Mr. and Mrs. James Hartness, Mr. and Mrs. Wm. H. Wiley, Calvin W. Rice, Mr. and Mrs. Willis E. Hall, Mr. and Mrs. Henry L. Gantt and Dr. Hele-Shaw. Music was furnished during the evening by the Imperial Orchestra.

SATURDAY, JULY 30

All-day excursions to Windsor and Marlow occupied Saturday, half of the party leaving London by special train for Windsor and proceeding by the special steam launches, Empress of India and Majestic, to Marlow, and the other half going by train to Marlow and thence to Windsor by the launches, His Majesty and Princess Beatrice, the two groups passing each other on the river. A view of the two parties is given herewith. In one case luncheon was served in Windsor at the Guildhall, with tea at the Compleat Angler and George and Dragon Hotels in Marlow, a picturesque fishing resort;

while in the other the party had luncheon on the launches and tea in the Guildhall. The trips on the launches were most enjoyable and gave a complete idea of life on the Thames, including the famous Henley regatta, then in progress. At Windsor, the Lord Mayor, Councillor C. F. Dyson, Alderman George Mitchell, Mem. I.Mech.E., Christopher Sainty, Mem.I.Mech.E., and George Willis, Assoc. Mem.I.Mech.E., personally conducted the party about this favorite residence of the English monarchs.

On Saturday evening Sir William H. White, Past-President of the Institution and an Honorary Member of the Society, together with Lady White entertained the Councils of the Institution and the Society at dinner in the Garden Club, which overlooks the grounds of the Japan-British Exposition at Shepherd's Bush. The picturesque Japanese Gardens, with their flavor of old-world romance, and the fine exhibits of ancient and feudal Japan, contrast strongly with the wonderful modern enterprise of both nations, and make the spot vastly interesting. Many Americans took advantage of the opportunity to see this Exhibition, assembling later in the room which had been especially set aside for the purpose by those in charge.

SUNDAY, JULY 31

Interest has long been manifested by the Society in the Sir Benjamin Baker Memorial Window in Westminster Abbey, which was unveiled on Dec. 3, 1909, and it was a pleasure to have an opportunity on Sunday evening of viewing it. The window, which is situated on the north side of the Nave, contains two lights having the figures of King Edward III and Abbot Simon Langham, under canopies, both lights being framed with borders containing niches which hold twelve statuettes and as many shields. Below these is the inscription on tablets held by the figures of angels: IN MEMORY OF SIR BENJAMIN BAKER, CIVIL ENGINEER, FORTH BRIDGE, ASSUAN DAM. B. 1840. D. 1907. The members assembled in the Dean's Yard and were conducted through the Abbey with its many famous spots by the Sub-Dean, the Very Reverend Dr. Duckworth. At the Vesper Service in the Nave, at seven o'clock, seats had been assigned to the representatives of the two societies and in his sermon the Bishop of Lewes gave a special greeting to the American visitors, of which 250 were present.

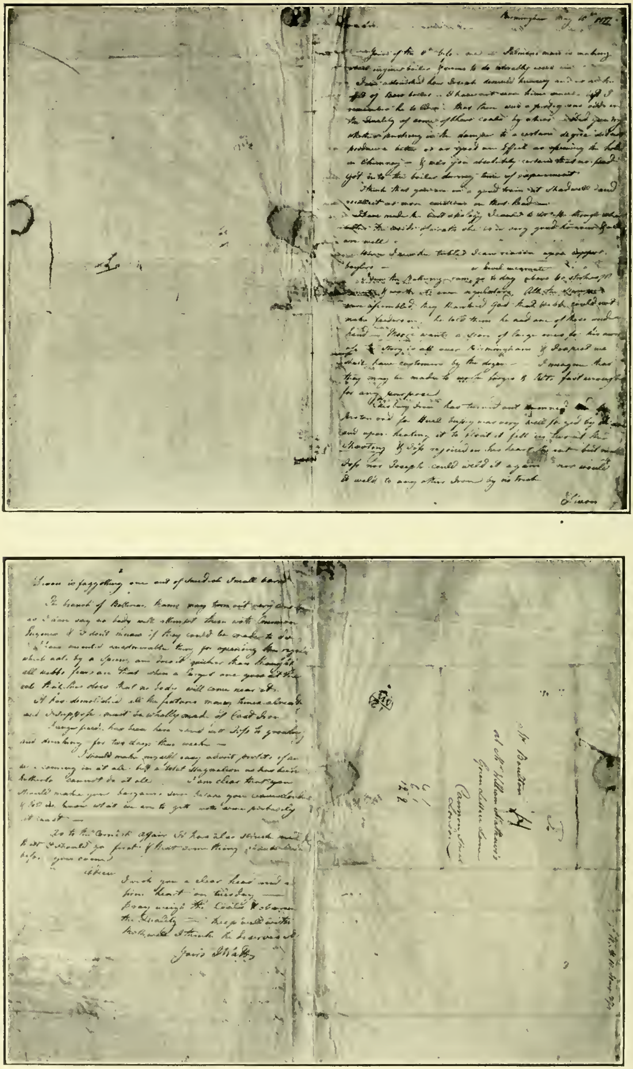
Taking his text from I Cor. xxii. 5, "There are differences of administration, but the same Lord," the Bishop declared this to be the exact opposite of the theory that everybody ought to be alike. Each had his special place and value, which were appraised differently by men but not by God. There were also differences of method, and not all seemed unsuccessful. Here amidst the memorials of the mighty dead we were never allowed to forget for one moment the vast range of God's workings in the life of men. Men great in war and great in peace, men far from perfect, each humanly weak, were here, but here because of the power of ministration that was in them. Differing widely in gift, method, opportunity, they were united in being searchers after the truth, interpreter's of God's plans and purposes for man, men who tried to serve their generation by the will of God. Sir Benjamin Baker was such a worker in the field of engineering service. The builder of Forth Bridge hardly needed any further remembrance, but as a man of noble character, as well as a scientific genius, he belonged among those who shared his talents and his strenuous life to interpret God's plans to men.

This service was regarded as the benediction of the Joint Meeting in England, which could not have been more appropriately ended.

On Monday evening, on the eve of departure on their second world tour, Ambrose Swasey, to whose forethought, wonderful tact and administrative ability it is not too much to say that a great part of the success of the Society's trip to England is due, together with Mrs. Swasey gave a dinner to the members of the Council of the American Society in the Hotel Russell, London. Leave takings were general on every side, some of the party going on to the Continent and others returning at once to America.

Among the kindly messages received during the Joint Meeting was the following telegram from the Junior Institution: "President Sir Henry Oram and Council Junior Institution Engineers desire join expressions welcome American Society Mechanical Engineers on visit Great Britain." Every member also received from the President of the Institution of Mechanical Engineers a very handsome brochure, containing portraits of the Presidents of the two organizations represented at the Joint Meeting, and brief biographical sketches of George Stephenson, Matthew Boulton, James Watt, Richard Trevithick, Robert Fulton, and William Symington, profusely illustrated with portraits and with quaint designs reproduced from Stuart's Anecdotes of Steam Engines, published in 1829.

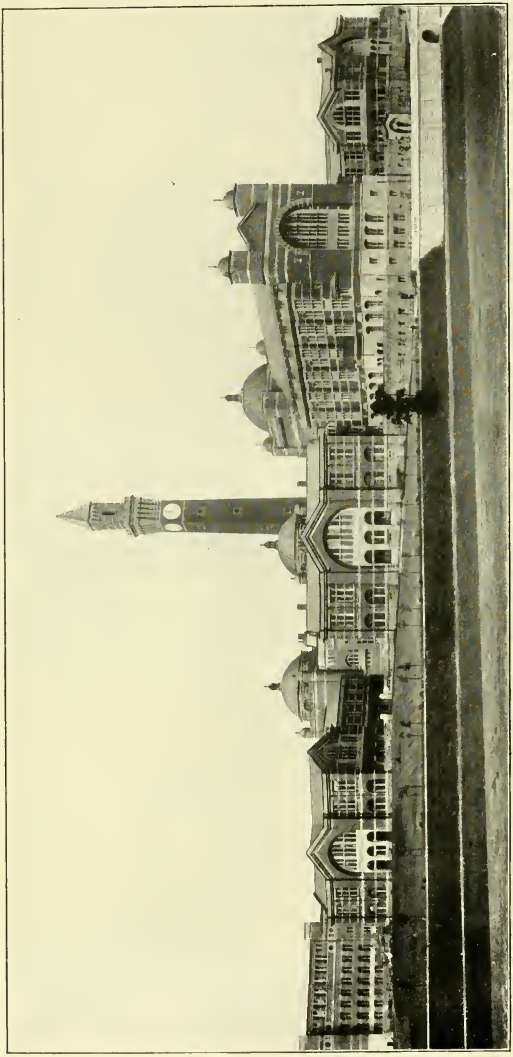
Such an account as is here presented can give but a glimpse of the visit to England, remarkable for its comfort and sociability and for the vast entertainment provided by the English Society, presenting as it did a happy combination of the technical and social features which were all blended together in the increased mutual regard, as removed from rivalry, of these two great national organizations. As no American can find himself a stranger in this land of his forefathers and his traditions, so no member of a professional organization on this side of the water can come in contact with those of a similar vocation in England without experiencing a sense of common ideals and common aims. Of the wonderful hospitality accorded by the English Institution too much cannot be said; nor can thanks ever express to the British members the gratitude and pleasure of their American guests. Not the slightest detail seems to have been omitted, the machinery of the entire gathering moving so perfectly as to be practically invisible. The finely prepared program, with its maps covering every inch of the ground to be traveled during the meeting, was an illustration of this wonderful attention to detail, including information, in addition to fullest data of meetings and trips, which met every possible want of the traveler, from restaurant locations and cab fares to the dates of departure of steamships carrying mails. The many welcoming hands held out on every side made the meeting a homecoming rather than a visit, to be looked back upon by all as a red-letter season in the life of the Society. The greeting of the English engineers when they shall next come to American shores, in a way worthy of their own welcome, is already joyfully anticipated by our members.



Watt Letter Presented to The American Society of Mechanical Engineers by Mr. George Tangye in Birmingham, July 26

Council House, Colmore Row, Birmingham

Colmore Row, Birmingham



University of Birmingham

Botanical Gardens, Edgbaston

Coventry, Showing the Spires of St. Michael's, St. Mark's and St. John's

Lichfield Cathedral from Minster Pool, showing the Three Spires

Ruins of Kenilworth Castle

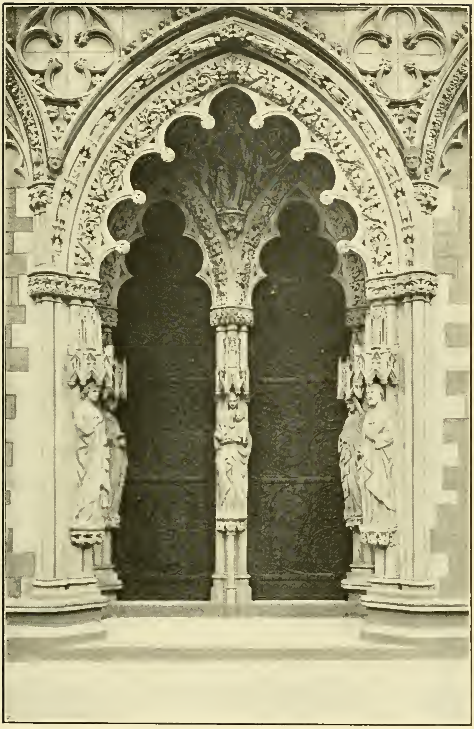
Stratford-upon-Avon

The Shakespeare Memorial Building appears at the right and the Church containing the Tombs of Shakespeare and Anne Hathaway at the left.

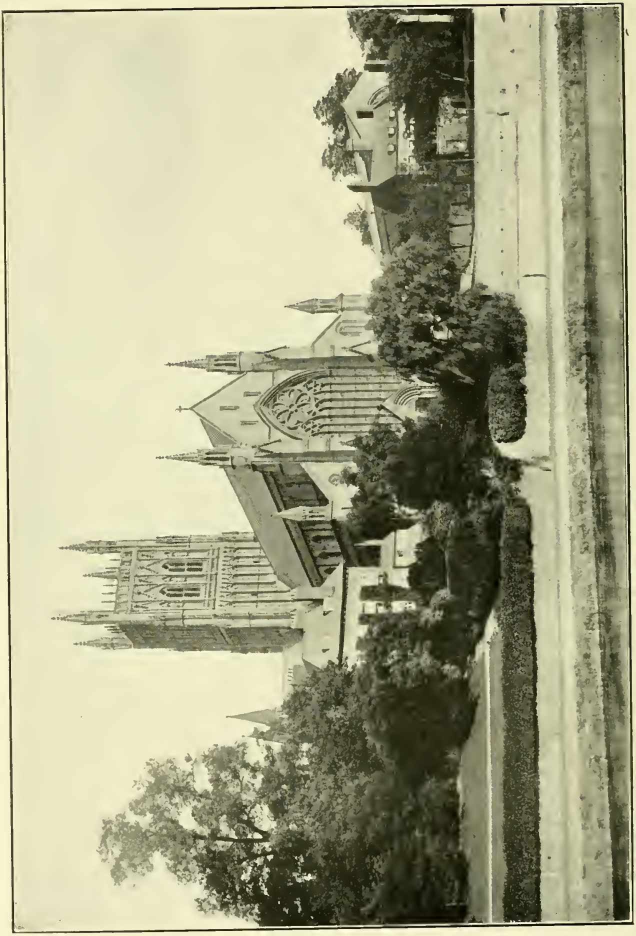
Warwick Castle on the River Avon

Shakespeare's House, Stratford-upon-Avon

Anne Hathaway's Cottage, Stratford-upon-Avon



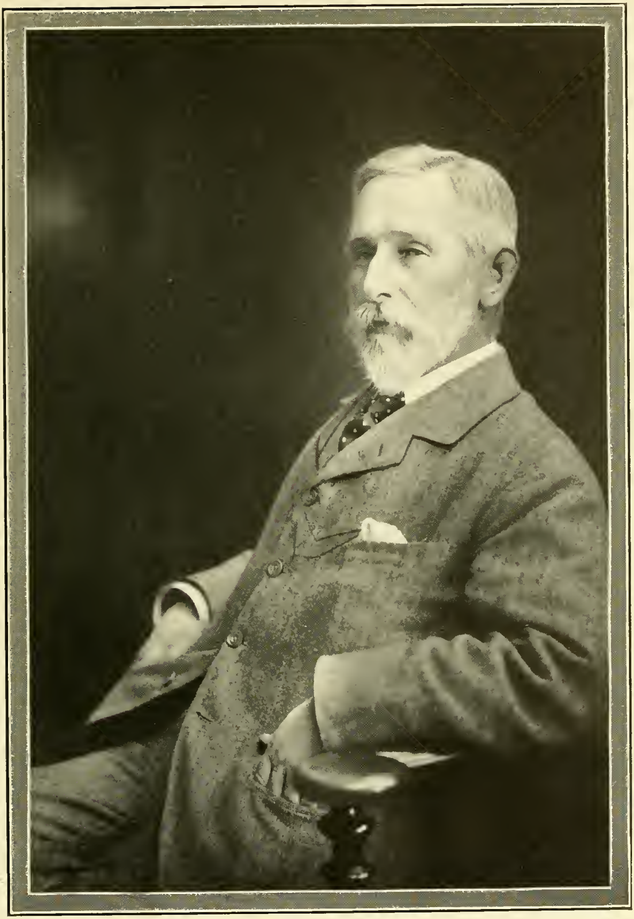
Lichfield Cathedral, Showing the West Door, Its Main Entrance



Worcester Cathedral

Windsor Castle from the Thames

Westminster Abbey, West Towers



Mr. George Tangye, Esq.

Who Presented to the Society the Watt Letter

RIGHT HON. JOSEPH CHAMBERLAIN

FORMER CHANCELLOR OF THE UNIVERSITY OF BIRMINGHAM, WHO STARTED THE MOVEMENT FOR ITS ESTABLISHMENT

SIR OLIVER J. LODGE
PRINCIPAL OF THE UNIVERSITY OF BIRMINGHAM

Alderman C. G. Beale
Vice-Chancellor of the University of Birmingham

THE TRANSMISSION OF HEAT IN SURFACE CONDENSATION

By George A. Orrok

TABLE OF CONTENTS

Historical Introduction 1773
Present Status of Heat Transmission through Metallic Tubes 1773
Methods and Apparatus 1775
Outline of Tests 1780
Variation of Heat Transfer with Temperature Difference 1784
Variation of Heat Transfer with Velocity of Water 1789
Variation of Heat Transfer with Velocity of Steam 1791
Effect of Air upon Heat Transmission 1794
Conclusions 1795

LIST OF APPENDICES

No. 1 List of Symbols Used and Tables Relating to Tests Made by the Author 1798
No. 2 Review of Results Obtained by Different Experimenters 1824
No. 3 References to Published Articles on Transmission of Heat through Tubes 1831

THE TRANSMISSION OF HEAT IN SURFACE CONDENSATION[1]

By George A. Orrok, New York
Member of the Society

Ever since the first use of steam in the arts, the condenser has been a very important part of the machinery designed for its utilization and the very simple laws governing condensation by mixture were early understood and formulated. With the advent of the surface condenser the problem became more complicated and the laws governing the transmission of heat through tubes or plates from wet vapor or condensing steam to water have been investigated by many physicists from Poisson in 1835, Peclet in 1841 and Joule in 1861 down to the present time. The earliest statement of the law of heat transmission in solids was made by Newton in 1690, while most of the mathematical work has been based on Fourier's classic published in 1882. Most of the earlier experimenters were misled by defects in their apparatus but by 1870 the existence of the gas film on the steam side of the tubes was suspected. The existence of the water film was suspected as early as 1861. Sir William Thomson stated in 1880 that the work of the earlier investigators was vitiated by the assumption that the temperature of the metallic surfaces was the same as the temperature of the medium in contact with them.

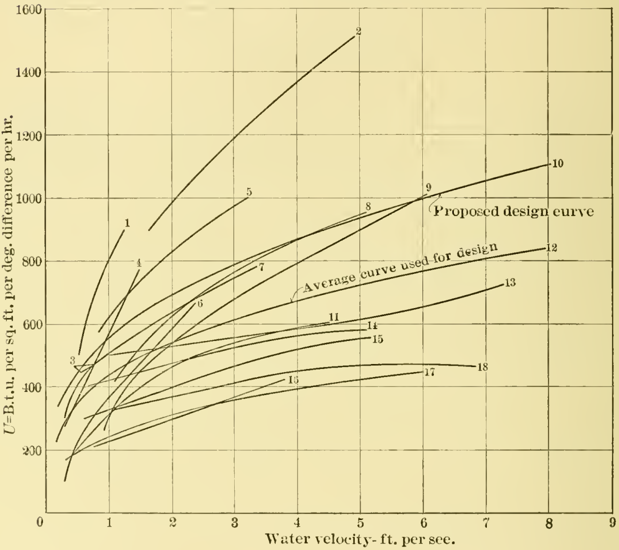
2 Since 1880 there have been attempts to ascertain the laws of heat transmission for condenser practice by many investigators: Werner and Hagemann in 1883, Ser in 1887, Richter in 1899 and Hepburn in 1901. The later experimenters have worked with actual machinery along what might be termed commercial lines.

3 The present status of the transmission of heat through metallic tubes from condensing steam to water according to various authorities may be stated as follows:

[1] For list of Symbols used see Appendix No. 1

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

a The quantity of heat transmitted by a unit of surface in unit time is proportional to the temperature difference (Joule, Rankine and most of the experimenters) or to the square of the temperature difference (Werner, Grashof and Weiss) between the media on the different sides of of the tube.



1—Josse—top of condenser
2—Josse—top of condenser (with baffles)
3—Richter—corr. copper tubes (horiz.)
4—Hepburn—corr. copper tubes (horiz.)
5—Josse
6—Hepburn—plain copper tubes (horiz.)
7—Ser
8—Weighton—plain tubes
9—Josse
10— $U = 22\sqrt{V_S}\sqrt[3]{0.023 + V_W}$ (V_S = 625)
11—Hagemann
12— $U = 17\sqrt{V_S}\sqrt[3]{0.023 + V_W}$ (V = 625)
13—Nicol—horizontal tubes
14—Stanton—water flowing down
15—Stanton—water flowing up
16—Allen—horizontal tubes
17—Joule
18—Nicol—vertical tubes

FIG. 1 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY

b The quantity of heat transmitted is proportional to some power of the water velocity ($V_w^{\frac{1}{3}}$ by Joule and Ser, $V_w^{\frac{1}{2}}$ by Hagemann and Josse, V_w^{1} by Stanton).

c The quantity of heat transmitted is proportional to some power of the steam velocity or mass flow ($V_s^{\frac{1}{2}}$ by Hausbrand and Ser, mass flow by Jordan).

d The quantity of heat transmitted is greatly affected by the amount of non-condensible vapors on the steam side of the tube (Bourne, Smith, Weighton, Morrison, McBride).

4 These differences of opinion did not trouble designers seriously as long as small condensers and vacuums of over two pounds absolute were the rule, but with the development of the turbine the need arose for condensers capable of condensing more than 200,000 pounds of water per hour at an absolute pressure of less than one pound. At first, excessive amounts of surface were installed but the first cost and upkeep led to more careful design and the demand for a more accurate knowledge of the laws of heat transmission under condenser conditions.

5 A careful study of the results of all the experiments available was made and plotted in Fig. 1. These curves show wide variation of values, but for a time the attempt was made to work from an average curve deduced by giving weights to the various experiments depending on the number of individual figures and their consistency. This average curve was used in the design of a number of large installations with excellent results.

6 The need for a careful determination of the whole question still existed and through the liberality of the management of The New York Edison Company the author was enabled to develop the apparatus and make the experiments described below, the results of which confirm and complete much of the work of earlier experimenters. It is hoped that they will aid condenser designers in producing apparatus better suited to the work, more satisfactory and more economical than ever before.

METHODS AND APPARATUS

7 The object in making these tests was to determine the heat transfer through various kinds of condenser tubes and the laws governing its variation under different conditions of steam temperature, pressure and velocity; velocity of circulating water; and mean temperature difference.

8 In order to obtain these data, a small surface condenser was constructed with a relatively small cooling surface and it was operated under conditions as nearly like actual condenser conditions as possible.

The steam inlet, dry vacuum, and circulating water lines were so arranged and controlled that any desired vacuum, any desired velocity of circulating water and any desired mean temperature difference could be maintained and that any one of these conditions could be varied through a considerable range quite independent of the other two. A hot well was constructed and so connected to the condenser that the temperature of the hot-well water (condensed steam) and its amount could be determined. Thermometers, pressure gages and a water meter were installed and a record was made of all desired data.

9 In order to fulfill these requirements, it was found necessary to make numerous changes in the apparatus as first constructed, which is shown in Fig. 2. It consisted of a condenser made of 5-in. extra-heavy wrought-steel pipe, with cast-iron screwed flanges on each end. To these were bolted cast-iron blank flanges, drilled and tapped for the various steam, water and vacuum connections. The condenser was of such a length that exactly 1 sq. ft. of cooling surface on a 1-in. outside diameter condenser tube was included between the inside faces of its end flanges. A condenser tube was passed through the center of the condenser and projected about 4 in. on each end through small stuffing boxes. These stuffing boxes, C_1 and C_2, are shown in detail in Fig. 4. A thermometer well and a vacuum gage connection were installed for recording the steam temperature and pressure. A hot well made of 5-in. wrought-iron pipe with a screwed and a blank flange on each end was connected to the condenser as shown. On the front of the hot well, a gage glass and a graduated scale were placed so that the height of the water could be observed and recorded, making it possible to calculate the weight of steam condensed for any given length of time. The valve G was used to empty the hot well at the end of a test. A thermometer was installed at H for observing the temperature of the condensed steam, the piping being so arranged that there was always a solid body of water surrounding the thermometer well. A $\frac{1}{2}$-in. line connected the top of the hot well to the vacuum line to equalize the pressures. The entire condenser and $\frac{3}{4}$-in. line to the hot well were covered with 4 in. of magnesia pipe covering to eliminate the effect of radiation.

10 The 1-in. circulating water line was taken from a 6-in. salt-water fire line in which was maintained a pressure of 90 lb. gage. This 1-in. line was connected to the condenser tube at each end by a piece of rubber hose which was wired at the ends to withstand a pres-

sure of about 20 lb. gage. Thermometer wells and thermometers were installed for observing the temperature of the circulating water at the inlet and the outlet of the condenser. The method of installing these thermometer wells is shown in detail in Fig. 4. A water meter was installed to register the amount of water flowing. The valve *P* was used to regulate the rate of flow.

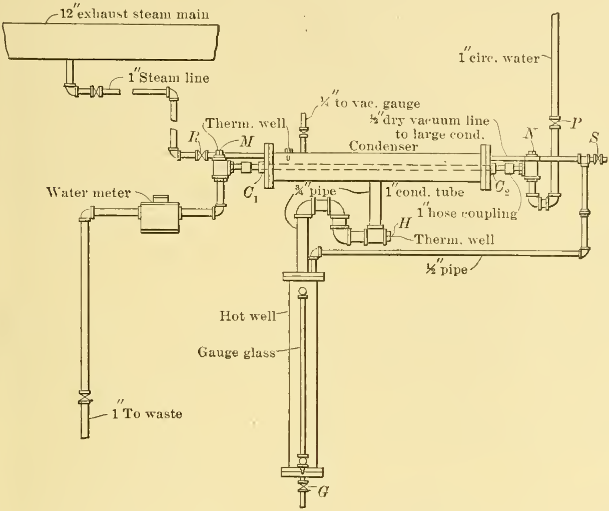
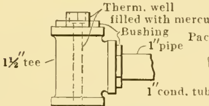
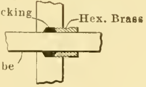


Fig. 2 Apparatus as First Constructed



Detail of Therm. wells at M and N



Detail of stuffing boxes-C_1 and C_2

Fig. 3 Fig. 4

Details of Apparatus

11 The 1-in. steam pipe was taken from the bottom of a 12-in. exhaust main which carried the exhaust steam from various auxiliary

engines to an open feed-water heater. The pressure in this line was about 2 lb. gage. The valve *R* was used to regulate the amount of steam admitted to the condenser.

12 The $\frac{1}{2}$-in. dry vacuum line was connected to the hot well of a large surface condenser which was operated at a vacuum of from 27.0 in. to 28.5 in. of mercury, or about 1 in. absolute pressure. All flanged joints were made up with $\frac{1}{8}$-in. rubber gaskets and all screwed joints with a heavy coating of red lead on the threads. One of the greatest difficulties encountered when running tests at a high vacuum was the prevention of air leakage. This difficulty was overcome to a great extent by a frequent and liberal application of a special heavy asphaltic paint to all joints. It was found possible to hold a vacuum within 0.5 in. of mercury of that in the large condenser when all valves were closed, except valve *S* in the vacuum line. With *S* closed, this vacuum would only drop from 27 in. to 26 in. in a period of 5 min.

13 All thermometers used in these tests were of the best make and could be read with accuracy to 0.1 deg. fahr. The water meter used was tested at various times and its error determined for all rates of flow. All heat transfer tests were extended over a period of 10 minutes after conditions had become constant and readings of temperatures and pressures were taken every 3 minutes.

14 A series of tests were made on various kinds of tubes at different vacua, but it was found that the heat transfers calculated from these tests had a maximum variation of 20 per cent for the same tube under exactly the same conditions as to steam temperature and pressure, mean temperature difference and velocity of circulating water. In these tests the vacuum was varied by regulating the steam admitted through the valve *R*, the vacuum line being kept wide open. It was found that to maintain a higher vacuum than 24 or 25 in. of mercury the steam valve *R* could be opened only a very small amount and that the steam entering the condenser was superheated as much as 50 deg. fahr. Another difficulty encountered was that at low vacuum, when the valve *R* was almost wide open, the heat transfer figured from the amount of steam condensed as measured in the hot well was considerably higher than that figured from the heat absorbed by the circulating water. This showed that the steam admitted must have contained considerable moisture. It was also found very difficult to maintain the rate of flow of the circulating water constant, due to the variation in pressure in the fire line from which it was taken. To overcome these difficulties, a number of

changes were made in the piping. A separator was installed in the steam line and the line was taken from the top of the 12-in. exhaust main instead of from the bottom. To aid in controlling the rate of flow of the circulating water, a pressure gage was installed in the line, and to maintain a constant rate of flow it was necessary only to keep this pressure gage indicating a steady pressure by regulating inlet valve *P*. In order to make it possible to maintain a high vacuum in the condenser without undue throttling of the steam, the dry vacuum line was increased in size to a 1-in. pipe.

15 Another series of tests was then made and it was found that the moisture in the steam at low vacua was practically eliminated. It was also possible to maintain a high vacuum, although there still seemed to be a more or less uncontrollable degree of superheat and the heat transfers for these high vacua tests were considerably lower than those at the lower vacua. A water jacket was now placed on the steam line with a ½-in. water connection from the circulating water line. This arrangement seemed to have but slight effect, however, and there was still found to be a considerable variation in heat transfer when an attempt was made to duplicate tests.

16 It was decided that the difficulty must lie with one of the following things:

a The quality of the steam as to amount of superheat, moisture, or entrained air and oil.
b The circulation or velocity of the steam.
c Air leakage.
d Cleanliness of the tubes.

17 To take care of the first item, it was decided to build a small independent boiler and generate steam as it was needed by means of a high-pressure steam coil. The boiler was constructed of two 14-in. flanged tees bolted together, with blank flanges bolted on the ends. It was connected to the condenser by a 5-in. pipe, the condenser being reduced in length and a 5-in. flanged tee bolted on one end, making the total face-to-face dimension the same as before. A steam coil, consisting of approximately 22 ft. of ¾-in. wrought-steel pipe, was placed in the boiler in such a way that it was entirely below the water level and still left a sufficient disengaging surface for the steam. Steam was supplied to this coil from a high-pressure steam main through a 1-in. pipe. Make-up water for the boiler was taken from a Croton water line through a ½-in. pipe. The bottom of the hot well was also connected to the boiler by a ¾-in. line containing a gate and a check valve so that the condensed steam could be returned

directly by gravity to the boiler. This arrangement obviated the necessity of breaking the vacuum and emptying the hot well after each test. A gage glass and a thermometer were installed, the whole apparatus being shown in Fig. 5.

18 To take care of the second item, the vacuum line was increased to 2 in. A $\frac{1}{4}$-in. connection for a vacuum gage was installed at *E* and a $\frac{3}{4}$-in. valve opening to atmosphere at *F*. With this arrangement, for any desired opening of the valve *S*, a constant velocity of steam through the condenser could be maintained by regulating the air valve *F* and the valve *K*, so that the steam passing through the valve *S* had a constant drop in pressure. This drop, due to velocity of the steam, was considered to be the difference in pressure as read at *E* and *D*.

19 The subject of air leakage was investigated by closing all valves except *S* and *K* in the vacuum line, when it was found possible to hold a vacuum in the condenser practically equal to that in the large condenser. The valve *S* was then closed and observations were taken as to the rate of fall of the vacuum in the apparatus. It was found that the vacuum would only drop from 28 in. to 27 in. of mercury in 15 min. These air-leakage observations were taken before every series of tests.

20 In order that the condition of the tubes as to cleanliness should not affect the heat temperature, all tubes used for testing were thoroughly cleaned every 10 or 12 tests. A series of tests made with this remodeled apparatus under constant conditions were found to have a maximum variation of not over 10 per cent and an average variation of 3 or 4 per cent. In these tests, the vacuum was varied by regulating the amount of steam admitted to the steam coil through the valve *T*.

21 Tests were run at vacua of 7, 15, 20, 25 and 27 in. of mercury, with circulating water at a temperature of about 40 deg. fahr. and a velocity of 8.6 ft. per sec. on the following kinds of tubes (tests 280 to 528 inclusive):

1 Admiralty
2 Admiralty, oxidized
3 Admiralty, vulcanized inside only
4 Admiralty, vulcanized outside only
5 Admiralty, vulcanized both sides
6 Admiralty, lead lined
7 Admiralty, old tube from condenser
8 Monel
9 Copper
10 Copper, aluminum lined
11 Aluminum bronze
12 Zinc
13 Tin
14 Cupro-nickel
15 Shelby steel
16 Glass

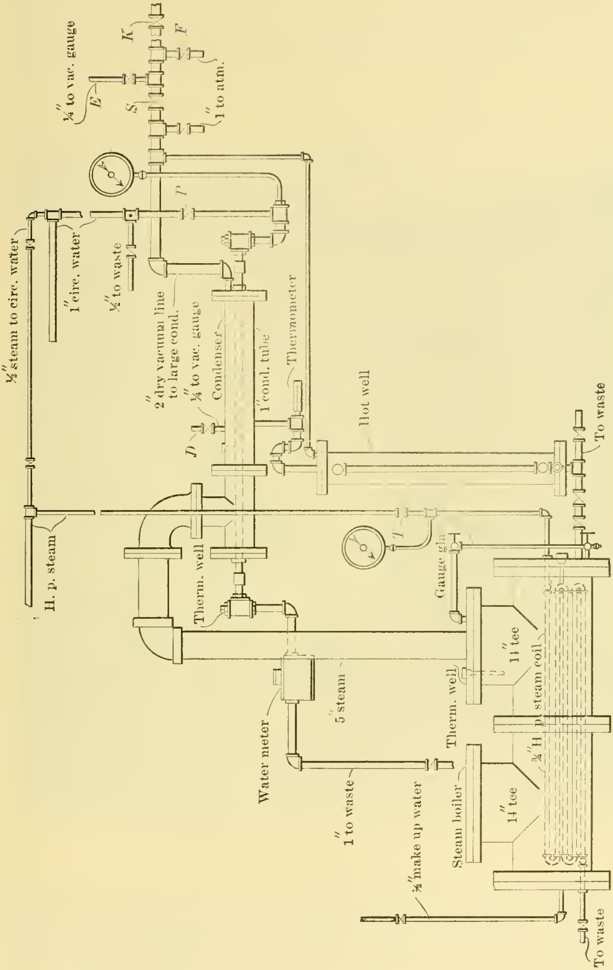


FIG. 5*a* APPARATUS AS ACTUALLY USED

The tests with the glass tube were difficult to make on account of the thinness and fragility of the tube and the tube was broken before all the desired tests were completed. In all these tests, it was found that the temperature of the steam was constant throughout the apparatus.

22 A series of tests was made on an Admiralty tube with a range in velocity of circulating water of from 1 to 11 ft. per sec. and a vacuum of 15 and 27 in. of mercury. In these tests the velocity of the circulating water was varied by regulating the valves at *P* and *V*, the pressure in the condenser tube being always kept above 10 lb. gage. All the above tests were made without changing the temperature of the circulating water, which was about 40 deg. fahr. (tests 529 to 622 inclusive).

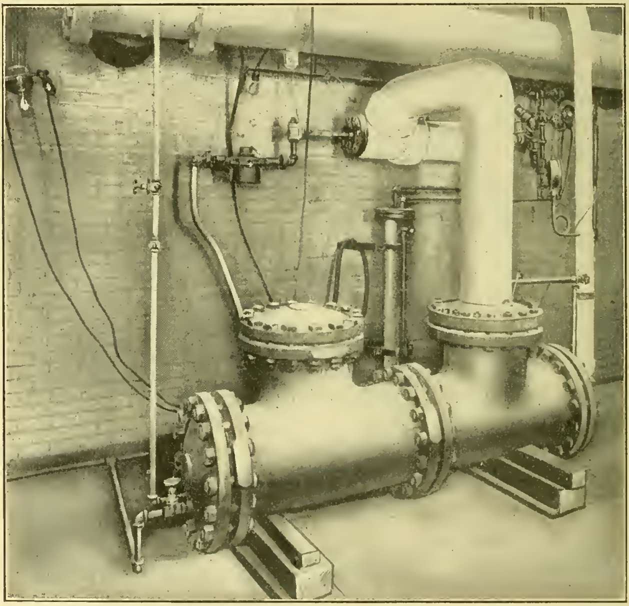


Fig. 5*b* Apparatus as Actually Used

23 To vary this temperature, a $\frac{1}{2}$-in. line was installed connecting the high-pressure steam line to the circulating water line as shown in Fig. 5. With this arrangement, it was possible to vary the temperature of the circulating water from 40 to 110 deg. fahr., thus varying the mean temperature difference without altering the other test conditions, and a series of tests was made on an Admiralty tube to determine the variation of heat transfer with changes of mean temperature difference (tests 623 to 727 inclusive).

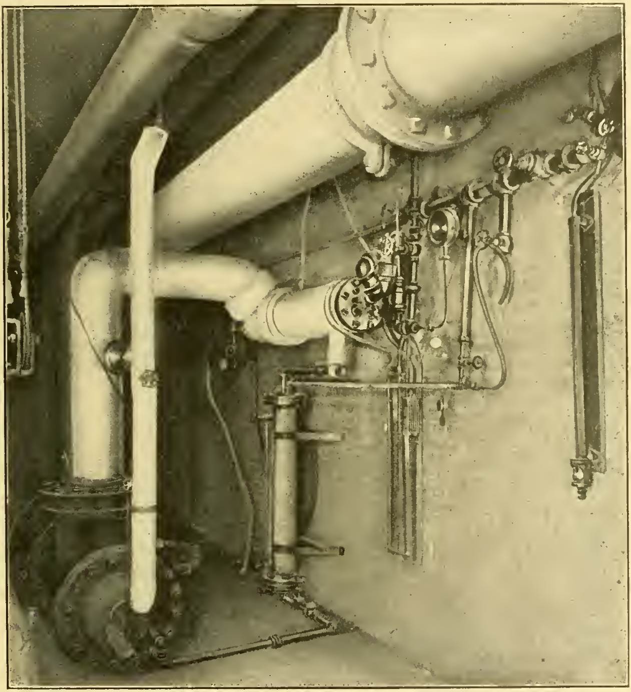


Fig. 5c Apparatus as Actually Used

24 Finally, a series of tests was made on all the various kinds of tubes with circulating water at a temperature of 85 deg. fahr. and velocity of 8.7 ft. per sec. and a vacuum of 27 in. of mercury (tests 728 to 771 inclusive).

VARIATION OF HEAT TRANSFER WITH TEMPERATURE DIFFERENCE

25 After the apparatus had been working some time and had been giving consistent results, a set of approximately 100 tests (623 to 727) was run to determine the possible variation of the heat transmission with the mean temperature difference. The quantities of cooling water were so large that the temperature rise (t_1-t_0) was always small and it was considered that the arithmetical mean of the water temperatures and the steam temperature might be

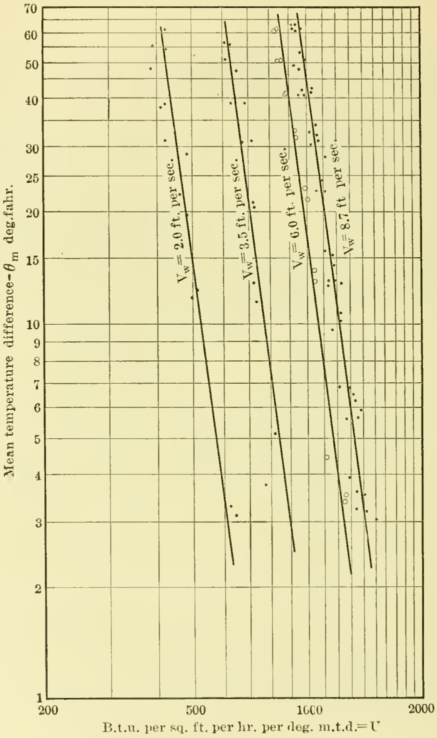


FIG. 6 RELATION OF COEFFICIENT OF HEAT TRANSFER TO TEMPERATURE DIFFERENCE

used without appreciable error in the calculation of the heat transfer. These tests were run at four different velocities, approximately 2, 4, 6, and 8 ft. per sec., the results were plotted on logarithmic paper and a smooth curve drawn through each set of plotted points. These curves were practically straight lines, as shown in Fig. 6, with a slope of about 0.125.

26 The relation may then be stated, $U = \frac{C}{\theta^{\frac{1}{8}}}$. Working from this, an expression may be obtained for the relation between the condensing surface or length of tube S and the temperature rise of the condensing water $(t_1 - t_0)$

$$S = C\left[(t_s - t_0)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}}\right]$$

and the true mean temperature difference is

$$\theta_m = \left[\frac{\frac{1}{8}(t_1 - t_0)}{(t_s - t_0)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}}}\right]^{\frac{8}{7}}$$

an expression which, in all practical cases, differs very slightly in numerical value from the geometrical mean

$$\theta_m = \frac{(t_1 - t_0)}{\log_e \frac{t_s - t_0}{t_s - t_1}}$$

27 The general expression connecting U and θ is then $U = \frac{K}{\theta^n}$, where n may have any positive or negative value excluding 0. The general expression connecting S and $(t_1 - t_0)$ will be

$$S = \frac{C_1}{n}\left[(t_s - t_0)^n - (t_s - t_1)^n\right]$$

and the true mean temperature difference is

$$\theta_m = \left[\frac{n(t_1 - t_0)}{(t_s - t_0)^n - (t_s - t_1)^n}\right]^{\frac{1}{1-n}}$$

For the case where $n = 0$ or $U = K$, a constant,

$$S = C \log_e \frac{t_s - t_0}{t - t_1}$$

and

$$\theta_n = \frac{t_1 - t_0}{\log_e \dfrac{t_s - t_0}{t_s - t_1}}$$

TABLE 1 VALUES OF U, S AND θ FOR VARIOUS ASSUMED VALUES OF N

S = cooling surface in sq. ft.
$N = U\theta$ = total heat transfer per sq. ft. per hr. in B.t.u.
U = heat transfer per sq. ft. per hr. per deg. m.t.d.
θ_m = m.t.d. = mean temperature difference
Q = circulating water per hr. in lb.
K = a constant determined by experiment
t_s = temperature of steam
t_0 = temperature of circulating water at inlet
t_1 = temperature of circulating water at outlet
t = any temperature between t_0 and t_1

1	$N = K$	$U = \frac{K}{\theta}$	$S = \frac{Q}{K}\left[(t_s - t_o) - (t_s - t)\right]$	$\theta = t_s - \frac{t_1 + t_o}{2}$
2	$N = K\theta$	$U = K$	$S = \frac{Q}{U} \text{Log}_e \frac{t_s - t_o}{t_s - t}$	$\theta = \frac{t_1 - t_o}{\text{Log}_e \frac{t_s - t_o}{t_s - t_1}}$
3	$N = K\theta^2$	$U = K\theta$	$S = \frac{Q}{K}\left[\frac{1}{t_s - t} - \frac{1}{t_s - t_o}\right]$	$\theta = \sqrt{(t_s - t_o)\ (t_s - t_1)}$
4	$N = K\theta^{\frac{1}{2}}$	$U = \frac{K}{\theta^{\frac{1}{2}}}$	$S = \frac{2Q}{K}\left[(t_s - t_o)^{\frac{1}{2}} - (t_s - t)^{\frac{1}{2}}\right]$	$\theta = \left[\frac{\frac{1}{2}(t_1 - t_o)}{(t_s - t_o)^{\frac{1}{2}} - (t_s - t_1^{\frac{1}{2}})}\right]^2$
5	$N = K\theta^{\frac{7}{8}}$	$U = \frac{K}{\theta^{\frac{1}{8}}}$	$S = \frac{8Q}{K}\left[(t_s - t_o)^{\frac{1}{8}} - (t_s - t)^{\frac{1}{8}}\right]$	$\theta = \left[\frac{\frac{1}{8}(t_1 - t_o)}{(t_s - t_o)^{\frac{1}{8}} - (t_s - t_1)^{\frac{1}{8}}}\right]^{\frac{8}{7}}$.
6	$N = \frac{K}{\theta^{n-1}}$	$U = \frac{K}{\theta^n}$	$S = \frac{Q}{Kn}\left[(t_s - t_o)^n - (t_s - t)^n\right]$	$\theta = \left[\frac{n\,(t_1 - t_o)}{(t_s - t_o)^n - (t_s - t_1)^n}\right]^{\frac{1}{1-n}}$

In Table 1 these values for U, S, θ_m and N (the total quantity of heat transferred) are tabulated and the curves of temperature rise and values of θ_m are plotted in Fig. 7 for certain steam and water temperatures.

28 Only two investigators, so far as I have been able to determine, have attempted experimentally to verify the law of the rise of temperature of condensing water in its passage through the condensing tube.

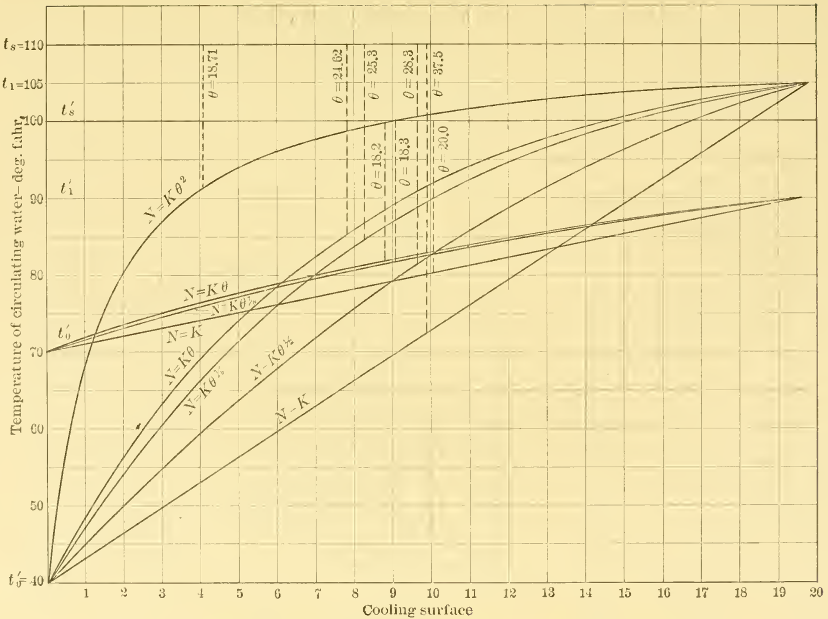


FIG. 7 CURVES OF TEMPERATURE RISE UNDER CERTAIN ASSUMPTIONS

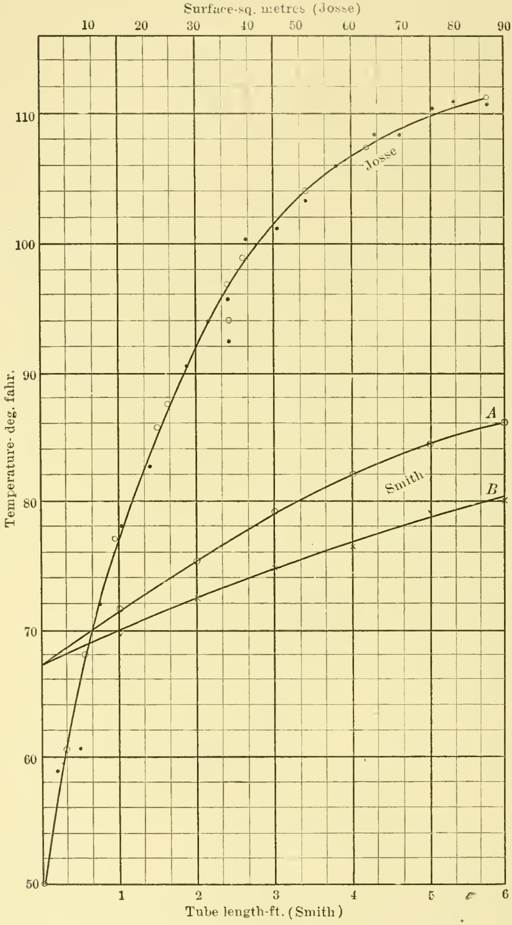


Fig. 8 Experimental Curves of Temperature Rise

J. Alex. Smith[1] experimented with a tube 6 ft. long, and Professor Josse[2] used a surface condenser approximately 86 sq. m. of surface. Neither experimenter gives his actual numbers but shows his results in a curve. Smith gives a second curve showing the deviation of his experimental numbers from the geometrical series which best represents his results. These curves are shown in Fig. 8 and the variation from the geometrical curve may be clearly seen. It is unfortunate that further accurate experiments have not been made on this particular phase of the subject, but none of these results are inconsistent with the conclusions arrived at from the author's experiments. In fact, the variations between the geometrical curve found by Josse and Smith and the writer's experiments are smaller than the variations of the actual points and the theoretical points plotted in Fig. 8.

VARIATION OF HEAT TRANSFER WITH VELOCITY OF WATER

29 A series of practically 100 tests was run to determine the variation of heat transferred to the velocity of the circulating water (tests 529 to 622 inclusive). These tests were run at various velocities from 1 to 11 ft. per sec. and the results are plotted in Fig. 9. These tests were run at two different vacua, 15 in. and 27 in. approximately, and the figure shows how closely the heat transmission varies with the square root of the water velocity. The third curve in Fig. 9 is a curve of total heat transmitted and apparently varies according to the same law.

30 The earlier investigators found somewhat different results. Josse and Foster have both taken advantage of the researches of Professor Ser of the School of Arts and Manufactures of Paris. Josse gives his results in a set of curves, while Foster gives a set of numbers. I have not been able to find the original figures. The numbers given by Foster and scaled from Josse's curves in metric measures are as follows:

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[1] London Engineering, Mar. 23, 1906.

[2] Zeitschrift des Vereins Deutscher Ingenieure, Feb. 27, 1909.

TABLE 2 SER'S NUMBER FOR U

V_w m.	U cal.		V_w ft.	U B.t.u.	$\sqrt[3]{V_w}$	C	$\sqrt{V_w}$	C
	Foster	Josse						
0.10	1400	1400	0.328	287	0.69	416	0.573	501
0.20	2300	2230	0.656	464	0.868	534	0.811	572
0.30	2550	2550	0.984	522	0.994	525	0.992	526
0.40	2710	2710	1.31	555	1.093	507	1.143	485
0.50	2860	2860	1.64	586	1.18	496	1.28	458
0.60	3020	3010	1.967	617	1.252	493	1.402	440
0.70	3180	3180	2.295	652	1.318	495	1.515	430
0.80	3330	3330	2.622	682	1.378	495	1.62	421
0.90	3480	3480	2.95	712	1.435	496	1.717	415
1.00	3640	3640	3.28	745	1.485	501	1.81	412
1.10	3800	3800	3.61	778	1.532	507	1.9	409

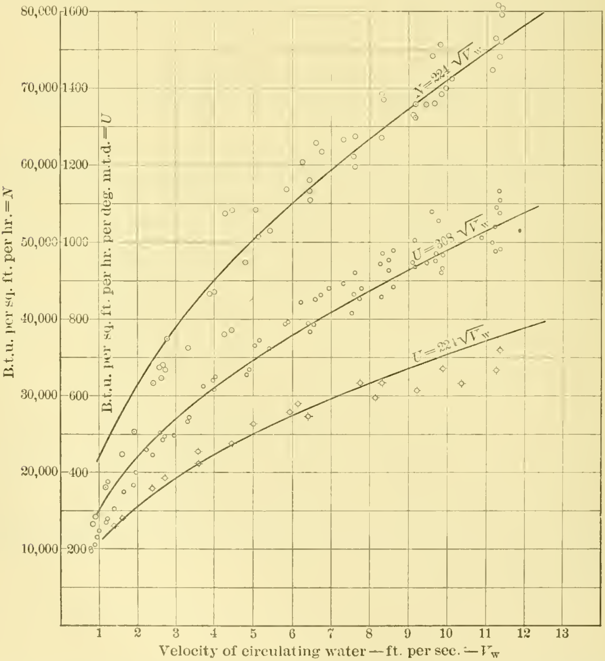

FIG. 9 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY (ORROK)

From these numbers, Ser's experiments may be best represented by $U = 490\sqrt[3]{V_w}$ or, if the transmission corresponding to 0.328 ft. per sec. be neglected, $U = 508\sqrt[3]{V_w}$, the variations from the square root curve being much greater.

31 Josse has also published a curve giving the results of Joule's experiments which follows very closely the expression $U = 239\sqrt[3]{V_w}$. Joule's actual numbers are available and have been recalculated. The low-vacuum tests, up to 2.5 in. of mercury absolute pressure, follow very nearly the above figure, but the mean of all tests within condenser conditions is more nearly stated by the expression $U = 315\sqrt[3]{V_w}$.

32 The work of these two experimenters is widely known and has had nearly universal acceptance until within a very few years, when a number of authorities have claimed that the fact might be better expressed by the formula $U = C\sqrt{V_w}$. In support of this view, Hagemann's experiments were cited and Josse's own experiments on small-size condensers appear to agree well with this expression. Stanton deduced from his experiments at Owens College that U was directly proportional to the velocity, but his numbers have never been published.

33 The curves in Fig. 10 show the relation between heat transfer and circulating-water velocity for all of the experimenters whose work has been recalculated in connection with this paper. There may be some doubt as to the constant in any one case, but all the results from the curves are merely the true average of the experimental figures. It is probable that the critical velocity was exceeded in all cases.

VARIATION OF HEAT TRANSFER WITH VELOCITY OF STEAM

34 That the velocity of the steam across the tube surface has an effect on the transmission has been asserted by a number of authorities. Hausbrand and Ser have considered that the heat transmission was proportional to the square root of the steam speed. Jordan maintains that the transmission is proportional to the mass flow of the steam. Most of the other investigators have neglected this. In the experiments, we have been unable to detect any effect on the heat transmission which might be charged to the velocity of the steam approaching the tube surface.

35 Let us consider a condenser consisting of a single tube, through which the cooling water is flowing, surrounded by an atmosphere of steam. Condensation will take place at the outer surface of the tube and the steam will rush in to the tube from all sides. Meanwhile, the space surrounding the tube will attain a constant pressure due to the regular influx of steam into the condenser and its condensation on the tube. This constant pressure will determine the temperature of the steam and if there is no air leakage the temperature will be that due to the saturated vapor of water at the constant pres-

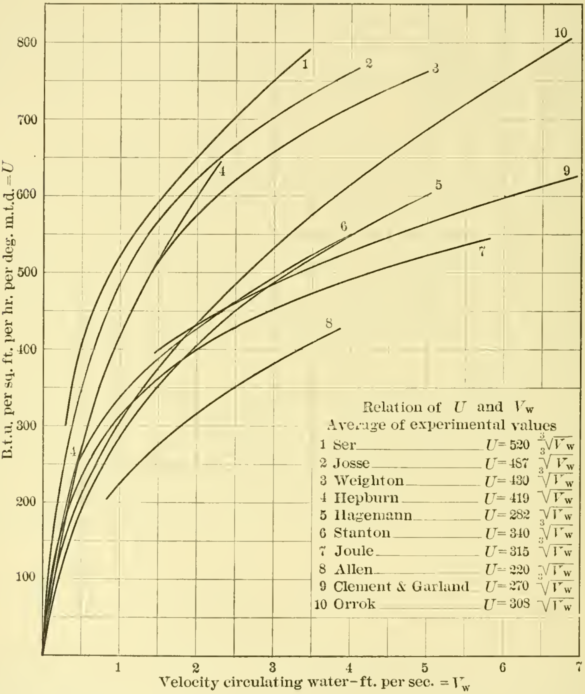

Fig. 10 Variation of Heat Transmission with Water Velocity (Various Authorities)

sure. It has been determined experimentally that the temperature and pressure remain sensibly constant throughout the condenser, except for an exceedingly minute space in the neighborhood of the tube surface.

36 There is then a constant flow normal to the surface of the tube besides such residual velocity as may be in the steam after its passage through the exhaust pipe. This residual velocity in practice is usually from 200 to 600 ft. per sec. and in turbine installations may be as high as 800 ft. per sec. In direction, it follows the axis of the eduction nozzle until deflected by the tubes, sides of the condenser or baffle plates and constantly loses velocity until, at the further end of the steam travel, this velocity is entirely lost. The

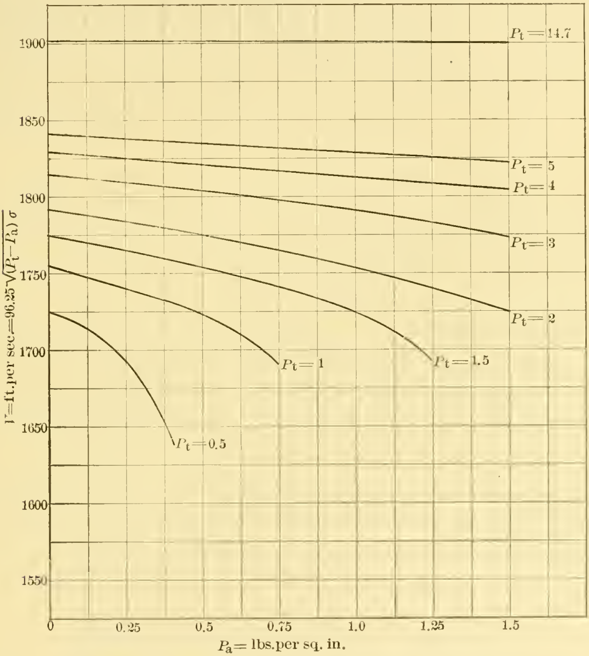

Fig. 11 Variation of Steam Velocity with Air

component of this residual velocity longitudinally to the tube is of no value in bringing a particle of steam to the condensing surface; neither is the component of this velocity normal to the tube surface, for its action is balanced by carrying away the steam on the opposite side of the tube. Its only action then is to distribute the steam among the tubes.

37 When a particle of steam comes in contact with the surface of the tube, it is immediately condensed and contracts enormously in volume. At atmospheric pressure the volume of water is approximately $\frac{1}{1660}$ of the steam volume. At 28 in. of vacuum, or 1 lb. abs., the contraction is about $\frac{1}{21,500}$, and at 29.,5 in., or ¼ lb. abs. 77,000 cu. ft. of steam condenses to 1 cu. ft. of water. The vacuum thus created induces a flow of steam normal to the steam surface, the velocity of which, neglecting friction, can easily be calculated for various conditions by means of the formula $V = \sqrt{2gh}$. Transforming this formula we get $V = 96.25 \sqrt{(P_t - P_a)\ \sigma}$, where P_t = vacuum pressure (lb. abs.), P_a = partial pressure due to air in the condenser, and σ = specific volume of steam at pressure $(P_t - P_a)$.

38 The velocity with which the steam particles strike the tube surface is apparently independent of the distance they travel before striking and is reasonably independent of the vacuum. The velocity varies from about 1750 ft. per sec. at 1 lb. abs. to about 1900 ft. per sec. at 14.7 lb. abs. or atmosphere. These values of V are shown in Fig. 11 and the effect of a small quantity of air in the condenser on the velocity of flow of the steam is shown to be very small.

THE EFFECT OF AIR UPON HEAT TRANSMISSION

39 During the early portion of these tests it was impossible even to approximate air-free steam, so that consistent transfer results could not be obtained. With the changing of the apparatus to a closed cycle, it was possible to keep the air down to a rather small quantity and the results obtained were much more consistent. It is probable in these cases that the partial air pressure never exceeded ½ in. and in most cases was below this point. By close attention to all possible sources of air leaks in the final tests run

from, say, No. 400 on, it is probable that the partial air pressure never exceeded $\frac{1}{4}$ in. and was sometimes much less than this.

40 The best experiments on the effect of air that I have been able to find were described by James Alexander Smith in a paper read before the Victorian Institute of Engineers on December 6, 1905, which was reprinted in London Engineering, March 23, 1906. An abstract of this paper will be found in Appendix No. 2. His results show that a partial pressure of air amounting to $\frac{1}{10}$ in. will reduce the heat transmission 25 per cent; $\frac{1}{4}$ in. of air will reduce it 40 per cent; and $\frac{3}{8}$ in. partial air pressure will reduce the heat transfer about 50 per cent. It is much to be regretted that Mr. Smith did not give his numbers, but the curves are sufficiently clear for use.

CONCLUSIONS

41 *a* The heat transferred from condensing steam surrounding a metallic tube to cold water flowing through the tube is proportional to the seven-eighths power of the mean temperature difference of the water and steam temperatures. This is equivalent to the statement that the coefficient of heat transfer, U, is inversely proportional to the eighth root of the mean temperature difference.

b The coefficient of heat transmission, U, is approximately proportional to the square root of the velocity of the cooling water.

c The coefficient U is independent of the vacuum and of the velocity of the steam among the tubes or in the condenser passages. It may be proportional to the square root of the velocity normal to the tubes, but in all common cases this velocity does not vary more than a tenth part.

d The effect of air on the heat transferred is very marked indeed, particularly at high vacua, and most of this air is due to leakage through the walls and joints of the apparatus. Working from Smith's curves and certain picked tests, where the volume of air could be calculated, the effect of the presence of air in reducing the value of U is as follows:

$$U = c\left(\frac{P_s}{P_t}\right)^5$$

where P_s is the partial pressure due to the steam and P_s is the total steam and air pressure.

e Taking the heat transfer of the copper tube as 1.00, under similar conditions the transfer for other materials is approximately as follows: copper, 1.00, Admiralty, 0.98, aluminum lined, 0.97, Admiralty oxidized (black), 0.92, aluminum bronze, 0.87, cupro-nickel, 0.80, tin, 0.79, Admiralty lead-lined, 0.79, zinc, 0.75, Monel metal, 0.74, Shelby steel, 0.63, old Admiralty (badly corroded), 0.55, Admiralty vulcanized inside, 0.47, glass, 0.25, Admiralty vulcanized both sides, 0.17. This coefficient (due to the material of the tube) will be designated by μ. Corrosion, oxidation, vulcanizing, pitting, etc., have also a marked effect in reducing the transfer. This reduction, best shown by the Admiralty tube which gave $\mu = 0.55$, may reduce the transfer at least 50 per cent.

f The foregoing conclusions may be expressed mathematically as follows:

$$U = K \frac{C \rho^5 \mu \sqrt{V_w}}{\theta^{\frac{1}{8}}}$$

where C = the cleanliness coefficient varying from 1.00 to 0.5
μ = the material coefficient varying from 1.00 to 0.17
ρ = the steam richness ratio, $\frac{P_s}{P_t}$ varying from 1.00 to 0.
V_w = the water velocity in ft. per sec.
θ = the mean temperature difference
K = a constant, probably about 630

The effect of the length of tube, or rather length of water travel, has not been considered and the design of the condenser must be such that there is a free steam passage to every tube.

g This expression for U is cumbersome to use and for modern turbine condenser work certain conditions may be taken as well settled. The guaranteed vacuum is usually 28 in. The entrance circulating water is usually 70 deg. and a 20 deg. temperature rise is considered economical. Under these conditions $\theta = 18.3$ and $\theta^{\frac{1}{8}} = 1.44$.

θ calculated on the geometrical curve is 18.2. For these cases it will be nearly as accurate and much simpler to calculate θ by the logarithmic method, neglecting θ in the denominator and using 435 or $\frac{630}{1.44}$ for K^1. The expression will then be $U = K^1 C P^5 \mu \sqrt{V_{\mathrm{w}}}$.

h The above equation agrees well with the results of a number of tests on full size condensers under varying conditions. There appears to have been no attempt to determine the amount of air handled by the air pump in these cases, but the amounts of air indicated by the formula are such as agree with the pressures and temperature taken. The measurement of the dry pump discharge has been undertaken and the author hopes to have more information on this point in the future.

42 In conclusion, the author wishes to acknowledge the efficient aid rendered him in conducting the experiments and calculating the results by his assistants P. E. Reynolds and H. R. Callaway.

APPENDIX NO. 1

LIST OF SYMBOLS USED AND TABLES RELATING TO TESTS MADE BY THE AUTHOR

V_w = water velocity, ft. per sec.
V_s = steam velocity, ft. per sec.
U = heat transmission coefficient, B.t.u. per sq. ft. per deg. difference per hr.
θ = temperature difference, deg. fahr.
θ_m = mean temperature difference, deg. fahr.
t_0 = temperature of inlet water
t_1 = temperature of overflow water
t = any temperature
t_s = temperature due to pressure of saturated steam
$\left.\begin{matrix} K \\ C \end{matrix}\right\}$ = constants
N = total heat transmitted per hour, B.t.u.
h = head, ft.
g = 32.2
σ = specific volume of steam at pressure $(P_t - P_a)$
P_t = vacuum pressure, lb. abs.
P_a = partial air pressure in condesnser, lb. abs.
P_s = partial steam pressure in condenser, lb abs.
μ = material coefficient
ρ = steam richness ratio, $\left(\frac{P_s}{P_t}\right)$
S = cooling surface, sq. ft.
Q = circulating water per hour, lb.
W = steam condensed per hour, lb.
$R = \frac{Q}{W}$
p = absolute pressure in condenser, in. of mercury

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES*

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.											
280	8510	53.2	160	8.43	2.67	110.5	36.01	42.52	6.48	71.22	774
281	8530	89.8	95	8.44	5.27	135.9	35.44	46.14	10.7	95.07	960
282	8670	134.2	64.5	8.56	9.82	160.9	35.36	51.04	15.68	117.7	1153
283	8660	166.2	52	8.55	15.09	178.8	36.5	55.5	19.0	132.8	1240
284	8550	211	40.5	8.44	32.0	215.5	37.3	61.2	23.9	166.3	1228
285	8570	157	54.7	8.47	14.99	178.4	36.07	54.20	18.13	133.2	1166
286	8550	125.5	68	8.44	9.99	161.4	37.73	52.58	14.85	116.2	1091
287	8625	83.5	103.3	8.53	4.95	132.1	38.30	48.15	9.85	88.9	955
288	8570	52.3	164	8.47	2.95	112.0	36.70	42.98	6.28	72.2	755
289	8570	180.0	47.7	8.47	22.82	197.9	39.15	59.63	20.48	148.5	1181
290	8550	178	48.1	8.44	22.92	198.2	37.75	58.05	20.3	150.3	1154
291	8625	55.2	156	8.53	2.79	116.2	35.8	42.38	6.58	77.09	737
292	8650	82.1	105	8.55	4.89	133.8	35.48	45.13	9.65	93.44	893
293	8570	124.2	69	8.47	9.90	161.6	35.43	50.10	14.68	118.9	1057
294	8625	152	57	8.53	14.90	178.8	36.40	53.73	17.43	133.8	1123
295	8525	174	49	8.42	22.52	197.6	36.38	56.38	20.00	151.3	1126
296	8750	55	159	8.64	3.06	117.6	37.53	43.98	6.45	76.8	734
297	8950	79.9	112	8.85	5.11	135.7	37.95	47.03	9.08	93.2	872
298	8900	120	74	8.80	9.91	161.4	37.00	50.65	13.65	117.5	1033
299	8825	149.5	59	8.72	14.98	179.2	36.45	53.20	16.75	134.4	1100
300	8825	174	50.7	8.72	22.56	198.0	36.93	56.23	19.30	151.4	1125
301	8875	120	73.8	8.77	9.86	161.3	36.65	50.33	13.68	117.8	1030
302	8370	59.7	140	8.27	3.28	118.8	37.3	44.6	7.3	77.85	785
303	8570	86.7	99	8.47	5.46	137.3	37.23	47.5	10.27	94.93	928
304	8525	125	68.2	8.42	10.63	164.3	36.1	50.73	14.63	120.9	1030
305	8525	148	57.7	8.42	15.53	180.4	36.17	53.32	17.15	135.7	1077
306	8475	167	50.6	8.37	23.13	198.8	36.92	56.27	19.35	152.2	1078
307	8420	65.2	129	8.32	4.26	129.3	36.63	44.53	7.9	88.7	751
308	8440	76.5	110.3	8.35	5.69	136.2	39.03	48.25	9.22	92.6	840
309	8600	112.5	76.3	8.50	10.15	160.7	39.08	52.35	13.27	115.0	991
310	8550	137	62.4	8.44	15.17	178.3	38.78	54.63	15.85	131.6	1030
311	8650	162	53.4	8.55	22.56	197.5	38.53	56.85	18.32	149.8	1058
312	8600	168	51.0	8.50	29.90	212.1	38.83	57.83	19.0	163.8	998
313	8925	54.5	164	8.82	3.04	115.6	39.33	45.6	6.27	73.1	765
315	8600	76.0	113.3	8.50	5.14	135.1	39.28	48.25	8.97	91.3	845
316	8600	109	78.7	8.50	10.02	161.3	39.0	51.83	12.83	115.9	952
317	8690	136	63.7	8.60	15.02	178.7	38.08	53.6	15.52	132.9	1015
318	8690	158	55.0	8.60	22.67	197.7	40.68	58.48	17.80	148.1	1043
319	8300	48.8	170	8.20	3.05	117.3	39.42	45.45	6.03	74.9	668
320	8300	74.5	111.5	8.20	5.03	135.0	38.4	47.5	9.1	92.05	821
321	8370	106	79.0	8.27	10.05	161.9	39.9	52.73	12.83	115.6	930

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* Tests 220 to 336 inclusive made without removing tube from apparatus. When removed tube was found to be covered with an accumulation of the black paint which was used on gaskets and joints to stop air leakage.

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
				Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.							
322	8550	130	65.7	8.44	15.12	179.5	40.3	55.35	15.05	131.7	977
323	8440	151	55.9	8.35	22.65	197.5	38.15	55.65	17.5	150.6	982
324	8690	157	54.7	8.60	30.0	212.1	38.73	56.45	17.72	164.5	937
325	8750	172	50.8	8.64	34.06	218.8	38.83	57.83	19.0	170.5	975
326	8750	179	48.8	8.64	41.8	229.4	38.3	57.95	19.65	181.4	948
327	8650	191	45.2	8.55	60.9	250.2	37.98	58.88	20.9	202.1	895
328	8600	159	54.1	8.50	29.5	211.2	38.45	56.35	17.9	164.8	935
329	8650	166	51.9	8.55	35.5	220.9	39.02	57.6	18.58	172.6	932
330	8600	172	49.9	8.50	42.7	230.5	38.88	58.08	19.20	182.0	907
331	8550	187	45.6	8.44	61.4	250 4	40.2	60.88	20.68	199.9	885
332	9125	161	56.5	9.02	30.0	212.7	37.95	55.1	17.15	166.2	942
333	9025	174	51.7	8.92	35.6	221.6	38.0	56.65	18.65	174.0	967
334	8900	182	49.0	8.80	42.7	230.3	37.92	57.5	19.58	182.6	955
335	8850	197	44.9	8.75	61.5	251.5	38.55	59.6	21.05	202.4	920
336*	8300	104	80.0	8.20	9.9	161.8	37.5	50.13	12.63	118.0	888
337†	8700	118	73.5	8.60	9.9	161.5	38.18	51.95	13.77	116.4	1028
338	8900	67.3	132	8.80	4.06	126.0	40.6	48.33	7.73	81.5	845
339	8840	78.7	111	8.74	5.02	133.8	40.1	49.3	9.20	89.1	913
340	8770	116	75.5	8.66	9.9	161.6	38.33	51.73	13.4	116.6	1010
341	8770	138	63.7	8.66	14.6	179.1	38.7	54.23	15.53	132.6	1027
342	8620	149	57.8	8.51	22.5	197.8	39.8	56.7	16.9	149.6	975
343	8650	133	64.8	8.55	22.5	197.6	39.4	54.48	15.08	150.7	867
344	8770	115	76.4	8.66	14.9	178.8	39.03	52.0	12.97	133.3	853
345	8650	94.0	92.0	8.55	9.9	160 9	38.85	49.83	10.98	116.6	823
346	8620	65.2	132	8.51	5.3	135.8	39.08	46.8	7.72	92.9	718
347	8890	69.5	128	8.77	3.01	115.5	41.83	49.83	8.00	69.7	1020
		New Admiralty Tube Installed. Tube Cleaned Every 8 or 10 Tests									
348	8700	91.3	95.2	8.59	5.02	133.8	40.58	51.25	10.67	87.9	1055
349	8620	122	70.5	8.51	9.9	161.5	39.85	54.20	14.35	114.5	1080
350	8700	160	54.3	8.59	14.8	178.7	37.73	55.93	18.2	131.9	1200
351	8700	186	46.7	8.59	22.5	197.9	38.23	60.2	21.97	148.7	1285
352	8470	67.7	125	8.36	3.00	115.3	39.45	47.65	8.20	71.7	970
353	8620	90.4	95.4	8.51	5.01	133.7	39.28	49.93	10.65	89.1	1032
354	8470	120	70.4	8.36	9.90	160.1	37.98	52.33	14.35	114.9	1057
355	8470	152	55.8	8.36	14.8	178.8	40.2	57.9	17.7	129.7	1155
356	8540	188	45.5	8.44	22.5	197.6	44.98	66.48	21.5	141.8	1295
357	8470	179	47.4	8.36	22.5	197.5	45.18	65.8	20.62	142.0	1230
358	8540	149	57.3	8.44	14.8	178.5	42.85	60.10	17.25	127.0	1157
359	8650	123	70.3	8.55	10.0	161.8	41.90	56.25	14.35	111.7	1112
360	8650	87.7	98.7	8.55	5.02	133.7	41.55	51.85	10.30	87.0	1025
361‡	8650	68.5	126	8.55	3.00	116.3	42.5	50.63	8.13	69.7	1010
362	8810	90.8	97	8.70	5.00	135.1	42.58	53.05	10.47	87.3	1055

* Test 336 made before cleaning tube.
† Test 337 made after cleaning tube.
‡ Tests 361 to 369 inclusive made with dry vacuum line wide open.

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, Q/W = R	Velocity of Water in Tubes, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	*Q*	*W*	*R*	V_w	*p*	t_s	t_0	t_1	$t_1 - t_0$	θ_m	*U*
			New Admiralty Type Bronze Tube, Being Cleaned Every 8 or 10 Tests								
363	8650	129	67	8.55	10.00	161.7	41.58	56.5	14.92	112.7	1145
364	8650	162	53.4	8.55	15.19	179.6	38.58	57.03	18.45	131.8	1210
365	8620	195	44.3	8.51	22.79	198.2	40.8	62.9	22.1	146.4	1297
366	8810	222	39.7	8.70	22.77	198.1	42.0	66.63	24.63	143.8	1505
367	8770	169	52	8.66	15.07	178.9	41.68	60.7	19.02	127.7	1307
368	8770	135	65.1	8.66	10.09	161.9	45.4	60.78	15.38	108.8	1237
369	8810	94.2	93.6	8.70	5.09	134.6	45.48	56.33	10.85	83.7	1142
370	8770	69.0	127	8.66	3.11	117.0	44.68	52.73	8.05	68.3	1032
371	8500	44.7	190	8.40	2.28	105.4	46.35	51.8	5.45	56.3	822
372	8440	57.3	147	8.32	3.75	116.3	42.03	49.03	7.00	70.8	832
373	8540	60.3	[illegible]	8.44	5.22	136.1	45.2	53.45	8.25	86.8	812
374	8390	91.3	91.8	8.29	10.2	162.2	45.9	56.8	10.9	110.9	825
			Admiralty Tube, 1 in. Outside Diameter, 18 B.W.G.								
375	8620	111	77.5	8.51	15.22	179.5	44.53	57.28	12.75	128.6	847
376	8500	126	67.5	8.40	23.0	198.5	46.05	60.6	14.55	145.2	852
378	8280	51.6	160	8.17	2.63	110.7	49.03	55.48	6.45	58.4	912
379	8470	74.2	114	8.36	5.00	132.8	48.58	57.48	8.90	79.8	942
380	8570	106	81	8.47	9.78	160.1	43.80	56.28	12.48	110.1	973
381	8540	125	68	8.44	14.78	178.4	44.60	59.15	14.55	126.5	982
382	8540	161	53	8.44	22.33	196.9	43.62	62.13	18.50	144.0	1098
383	8620	122	70.4	8.51	9.58	159.6	44.25	58.60	14.35	108.2	1142
384	9150	63	145	9.03	2.80	114.1	47.8	54.90	7.1	62.7	1035
385	9040	75.2	120	8.92	3.85	125.4	48.5	56.98	8.48	72.7	1055
386	9120	62.8	145	9.00	2.80	113.8	47.55	54.63	7.08	62.7	1030
387	8840	75.5	117	8.74	3.82	124.8	46.53	55.13	8.7	74.0	1040
388	8960	63.0	142	8.85	2.80	113.6	45.5	52.7	7.2	64.5	1000
389	8720	74.0	118	8.62	3.82	124.7	46.65	55.33	8.68	73.7	1030
390	8925	85.8	104	8.81	4.77	133.5	46.5	56.28	9.78	82.1	1063
391	8925	49.5	180	8.81	2.07	103.9	52.3	58.03	5.73	48.7	1052
392	9000	60.7	149	8.89	2.93	115.0	47.88	55.25	7.37	63.4	1045
393	9040	81.4	111	8.92	4.90	133.0	45.18	54.3	9.12	83.3	990
394	8840	80.5	107	8.74	4.93	133.1	52.98	62.45	9.47	75.4	1110
395	9000	123	73.3	8.89	9.91	161.0	52.4	66.18	13.78	101.7	1220
396	8925	151	59.7	8.81	14.96	179.0	51.42	68.1	16.68	119.2	1248
			Copper Tube, 1 in. Outside Diameter, 16 B.W.G.								
397	8730	53.5	163	8.65	2.98	115.6	46.98	53.28	6.30	65.5	840
398	8840	71.2	124	8.77	4.95	133.6	46.95	55.18	8.23	82.5	872
399	8890	70.5	126	8.80	4.95	133.3	42.73	50.83	8.10	86.5	832
400	8770	94.3	93.2	8.70	9.9	161.0	45.25	55.75	10.5	111.5	827
401	9000	57.5	157	8.92	3.26	118.1	48.6	55.13	6.53	66.2	888
402	8810	81.5	108	8.73	5.23	135.5	46.32	56.75	9.43	84.0	990
403	8890	119	75.0	8.80	10.23	162.1	48.85	62.2	13.35	106.6	1110
404	8970	134	67.0	8.89	15.26	179.8	45.8	60.53	14.73	126.6	1060
405	8925	152	58.8	8.80	22.97	198.3	49.1	65.75	16.65	140.9	1053

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.
MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Copper Tube, 1 in. Outside Diameter, 16 B.W.G.											
406	9040	134	67.3	8.92	15.2	179.5	46.45	61.15	14.7	125.7	1057
407	8810	114	77.3	8.70	10.15	162.0	44.75	57.7	12.95	110.8	1030
408	8925	83.5	107	8.81	5.2	135.0	45.55	55.08	9.53	84.7	1005
409	8810	63.4	139	8.70	3.2	117.5	49.18	56.53	7.35	64.6	1003
Aluminum Bronze Tube, 1 in. Outside Diameter, 18 B.W.G.											
410	8650	66.5	130	8.55	3.29	118.1	44.68	52.58	7.90	69.5	984
411	9040	83.5	108	8.92	5.17	135.1	49.38	58.8	9.42	81.0	1047
412	8970	108	83.2	8.85	10.22	162.0	48.50	60.53	12.03	107.5	1002
413	8925	119	75.0	8.81	15.19	179.2	44.1	57.3	13.2	128.5	918
414	8925	138	64.7	8.81	22.85	198.0	44.58	59.83	15.25	145.8	932
415	9000	142	63.5	8.89	22.87	198.1	43.48	58.80	15.42	147.0	945
416	8810	115	76.6	8.70	15.17	179.3	45.68	58.60	12.92	127.2	895
417	8770	108	81.5	8.66	10.14	161.7	47.28	59.68	12.4	108.2	1005
418	8770	76.2	115	8.66	5.09	135.4	47.63	56.43	8.80	83.4	925
419	8810	63.8	138	8.70	3.14	116.6	40.2	47.63	7.43	72.7	900
Copper Tube, 1 in. Outside Diameter, 16 B.W.G.											
420	8890	61.2	145	8.80	3.13	116.5	42.35	49.45	7.1	70.6	893
421	8700	78.4	111	8.60	5.08	134.1	42.35	51.55	9.20	87.1	918
422	8650	108	79.8	8.98	10.18	162.0	41.78	54.30	12.52	114.0	950
423	8730	127	68.5	9.05	15.07	178.9	41.90	56.33	14.43	129.7	973
424	8650	146	59.0	8.98	22.82	197.9	42.63	59.23	16.60	147.0	977
Cupro-Nickel, 1 in. Outside Diameter, 18 B.W.G.											
425	8840	57.3	154	8.74	3.09	116.0	42.48	49.15	6.67	69.2	853
426	9120	74	123	9.00	4.87	132.9	42.45	50.73	8.28	80.3	875
427	9120	101	90.6	9.00	9.81	160.6	42.00	53.15	11.15	113.0	898
428	8890	120	74	8.77	14.87	178.7	41.13	54.48	13.35	130.9	907
429	9080	145	62.6	8.96	22.56	197.4	40.63	56.28	15.65	148.9	953
431	8970	57.5	156	8.85	3.04	115.8	40.38	46.95	6.58	72.1	820
432	8840	72.4	122	8.74	4.94	133.6	41.35	49.7	8.35	88.1	838
433	8840	98.7	89.7	8.74	10.03	161.1	41.68	52.93	11.25	113.8	875
434	9000	117	76.8	8.89	14.98	178.9	48.6	61.48	12.88	123.9	935
435	8810	139	63.3	8.70	22.89	198.0	46.35	61.83	15.48	143.9	948
Aluminum-Lined Copper Tube, 1 in. Outside Diameter, 0.06 in. Thick											
436	8840	61.7	143	9.18	3.07	115.1	43.08	50.23	7.15	68.9	918
437	8925	82.6	108	9.25	5.07	133.9	42.2	51.63	9.43	87.0	967
438	9000	116	77.7	9.34	10.13	161.7	42.18	55.18	13.0	113.0	1033
439	9080	137	66.2	9.41	15.1	178.8	42.98	57.93	14.95	128.3	1058
440	9040	162	55.8	9.36	22.95	198.1	42.58	60.1	17.52	146.8	1078
441	8970	168	53.4	9.30	22.95	198.1	41.5	59.82	18.32	147.4	1110
442	9040	144	62.7	9.36	15.05	178.1	40.88	56.65	15.77	129.3	1098
443	8970	120	74.7	9.30	10.02	162.4	41.98	55.38	13.4	113.7	1055
444	9040	82.8	109	9.36	4.96	133.3	42.30	51.63	9.33	86.3	975
445	8890	59.7	149	9.21	3.09	115.9	42.05	48.95	6.90	70.4	887

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Monel Tube, 1 in. Outside Diameter, 18 B.W.G.											
446	8925	57.1	156	8.81	3.51	119.6	40.58	47.13	6.55	75.7	773
447	8810	68.2	129	8.70	5.01	133.3	40.80	48.68	7.88	88.6	783
448	8970	91.0	98.5	8.85	10.08	161.5	40.80	51.03	10.23	115.6	794
449	8840	107	82.5	8.74	14.96	178.5	40.50	52.5	12.0	132.0	805
450	8970	128	70.0	8.85	22.98	198.1	40.15	54.13	13.98	151.0	830
451	8810	126	70.0	8.70	23.01	198.1	40.0	54.0	14.0	151.1	817
452	9000	107	83.8	8.89	15.01	178.1	40.8	52.6	11.8	131.4	807
453	8890	89	100	8.77	9.95	160.5	41.13	51.2	10.07	114.3	792
454	8890	66.3	134	8.77	5.00	133.1	41.55	49.13	7.58	87.8	768
455	9040	55.4	163	8.92	3.42	118.8	40.95	47.25	6.30	74.7	762
Admiralty Tube, Oxidized, 1 in. Outside Diameter, 18 B.W.G.											
459	8840	129	68.7	8.74	15.04	178.9	44.98	59.38	14.4	126.7	1005
460	8840	151	58.5	8.74	22.94	198.2	45.25	61.98	16.73	144.6	1023
461	8810	149	59.0	8.70	22.95	198.5	43.98	60.55	16.57	146.2	998
462	9080	127	71.5	8.96	15.05	178.8	43.8	57.63	13.83	128.1	980
463	9040	103	88.0	8.92	10.02	161.4	46.33	57.8	11.48	109.3	958
464	8970	74.7	12.0	8.85	5.05	134.2	48.38	56.88	8.50	81.6	934
465	8890	63.0	141	8.77	3.67	123.2	47.13	54.38	7.25	72.9	885
466	9040	78.5	115	8.92	5.37	136.0	47.03	55.9	8.87	84.5	948
467	8810	108	81.3	8.70	10.39	162.6	45.55	57.85	12.3	110.9	977
Zinc Tube, 1 in. Outside Diameter, 18 B.W.G.											
469	9000	53.0	170	8.89	3.52	120.4	44.85	50.88	6.03	72.5	738
470	8925	65.0	137	8.81	5.49	137.1	44.1	51.5	7.40	89.3	740
471	8970	84.6	106	8.85	10.34	162.6	45.12	54.58	9.45	112.8	751
472	8840	100	88	8.74	15.32	179.8	44.15	55.4	11.25	130.0	765
473	8970	121	74	8.85	23.38	199.5	43.55	56.78	13.23	149.3	793
474	8925	46.2	193	8.81	3.36	118.8	49.5	54.8	5.30	66.7	712
475	8925	63.2	141	8.81	5.35	136.5	43.62	50.82	7.20	89.3	720
476	9080	82.5	110	8.96	10.35	162.4	46.33	55.45	9.12	111.5	740
477	9040	96.0	94.3	8.92	15.20	179.5	49.00	59.5	10.5	125.2	757
478	9040	115	78.3	8.92	23.07	198.5	49.10	61.6	12.5	143.1	787
Aluminum-Bronze Tube, 1 in. Outside Diameter, 18 B.W.G.											
479	8925	62.3	143	8.81	3.53	120.7	42.85	50.02	7.17	74.3	852
480	8925	75.6	118	8.81	5.38	136.6	42.4	51.02	8.62	89.9	857
481	8730	95.2	91.8	8.62	10.28	162.5	45.72	56.8	11.08	111.2	870
482	8890	112	79.5	8.77	15.28	179.9	52.28	64.73	12.45	121.4	910
483	9000	133	67.3	8.89	23.19	198.2	47.98	62.5	14.52	142.9	915
484	8840	65.0	136	8.74	4.03	126.5	45.10	52.82	7.52	77.6	857
485	9040	73.5	123	8.92	5.08	134.8	43.85	52.13	8.28	86.8	860
486	8730	95.0	92.0	8.62	9.95	160.75	44.55	55.55	11.0	110.7	868
487	8970	117	76.2	8.85	15.13	179.1	48.02	61.00	12.98	124.6	938
488	8890	133	67.1	8.77	23.03	198.5	49.32	64.12	14.8	141.8	927
489	9000	95.0	94.8	8.89	10.15	161.6	51.3	61.95	10.65	105.0	912

TABLE 3 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE WITH DRY VACUUM LINES ONLY SLIGHTLY OPEN

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, Lead Lined, 1 in. Outside Diameter, 0.088 in. Thick											
491	9000	55.2	163	10.54	4.02	125.6	49.98	56.25	6.27	72.5	778
492	8890	62.6	142	10.50	5.12	134.5	50.68	57.85	7.17	80.2	795
493	8770	87.7	100	10.36	10.01	161.1	51.35	61.4	10.05	104.7	845
494	8840	108	81.5	10.45	14.99	179.0	50.23	62.4	12.17	122.7	875
495	8810	129	68.3	10.41	22.84	198.0	49.73	64.08	14.35	141.1	895
496	8840	130	68.1	10.46	22.77	198.1	47.7	62.08	14.38	143.2	887
497	8650	110	78.5	10.23	14.94	178.9	45.63	58.25	12.62	127.0	860
498	8620	92.8	93.0	10.18	9.99	161.0	44.68	55.55	10.87	110.9	852
499	8620	69.0	125	10.18	5.86	139.1	44.9	52.98	8.08	90.1	773
Shelby Steel Tube, 1 in. Outside Diameter, 18 B.W.G.											
500	8970	55.0	163	8.85	3.49	120.0	45.88	52.15	6.27	71.0	788
501	8925	65.0	137	8.81	5.01	132.9	45.38	52.8	7.42	83.8	790
502	8840	82.6	107	8.74	10.03	161.1	46.35	55.83	9.47	110.0	762
503	8970	99.5	90.2	8.85	15.0	179.0	45.93	56.9	10.97	127.6	775
504	8970	111	80.5	8.85	22.80	198.1	49.88	62.03	12.15	142.1	765
505	8970	108	83.2	8.85	22.77	198.1	55.28	67.05	11.77	136.9	770
506	9040	94.5	95.7	8.92	14.89	178.4	51.95	62.28	10.33	121.3	770
Shelby Steel Tube with Coating of Rust											
507	8925	44.8	199	8.81	3.53	121.1	52.65	57.8	5.15	65.9	695
508	8840	55.5	159	8.74	5.23	135.3	49.3	55.68	6.38	82.8	682
509	8730	71.0	123	8.62	10.26	162.5	44.63	52.78	8.15	112.8	630
Tin Tube, 1 in. Outside Diameter, 0.055 in. Thick											
510	8840	47.2	187	9.12	3.59	120.8	57.25	62.73	5.48	60.8	797
511	8650	64.0	135	8.92	5.09	133.8	44.9	52.4	7.50	85.1	764
512	8890	87.0	102	9.15	10.17	161.4	44.4	54.2	9.80	112.1	778
513	8770	96.3	91.2	9.04	15.14	179.0	52.33	63.18	10.85	121.2	785
514	8570	113	75.5	8.84	23.17	198.6	51.7	64.53	12.83	140.5	783
515	8650	113	76.6	8.92	22.94	198.4	51.23	63.88	12.65	140.8	778
516	8970	96.6	93.0	9.24	15.12	178.8	52.7	63.35	10.65	120.8	790
517	8840	81.0	109	9.12	10.10	161.0	52.88	62.18	9.30	103.4	793
518	8700	60.8	143	8.98	5.10	133.5	50.95	58.05	7.10	79.0	781
519	8890	53.5	166	9.15	4.10	125.6	51.93	58.10	6.17	70.6	775
Old Admiralty Tube Taken from Large Condenser, 1 in. Outside Diameter, 18 B.W.G.											
520	8730	48.2	181	8.62	4.49	129.0	45.0	50.63	5.63	81.2	606
521	8620	69.0	125	8.51	9.87	159.8	53.2	61.28	8.08	102.6	675
522	8620	84.5	102	8.51	14.87	177.9	52.58	62.25	9.67	121.4	686
523	8650	103	84	8.55	22.87	197.9	50.23	61.88	11.65	141.8	710
524	8650	105	82.5	8.55	22.77	197.1	46.48	58.35	11.87	144.6	710
525	8730	43.0	203	8.62	3.51	121.1	52.68	57.73	5.05	65.9	667
526	8700	53.2	163	8.58	5.23	135.4	53.23	59.45	6.22	79.1	683
527	8840	73.0	121	8.74	10.28	162.3	54.2	62.5	8.30	103.9	704
528	8840	86.6	102	8.74	15.20	179.3	55.03	64.75	9.72	119.4	717

TABLE 4 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES

MADE TO DETERMINE EFFECT OF CIRCULATING WATER VELOCITY ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	t_1-t_0	θ_m	U
Old Admiralty Tube Taken from Large Condenser, 1 In. Outside Diameter, 18 B.W.G.											
529	11252	53.8	209	11.3	5.25	134.4	50.6	55.48	4.88	82.4	668
530	10530	51.6	204	10.4	5.28	135.5	49.75	54.75	5.00	83.2	634
531	9340	49.1	190	9.24	5.23	134.3	49.6	54.98	5.38	81.8	615
532	8240	47.3	174	8.15	5.23	134.1	50.05	55.93	5.88	81.1	595
533	6490	42.5	152	6.42	5.20	133.8	50.3	57.03	6.73	80.1	545
534	6030	42.7	141	5.97	5.25	134.1	52.3	59.55	7.25	78.2	558
535	4440	37.0	120	4 49	5.23	133.8	48.05	56.58	8.53	81.0	473
536	3640	33.0	110	3.60	5.25	133.9	50.23	59.53	9.3	79.0	428
537	1670	21.4	78	1.65	5.23	134.0	50.25	63.33	13.08	77.2	283
538	1440	19.7	73.1	1.43	5.12	134.8	52.5	66.45	13.95	75.3	267
539	2425	27.1	89.7	2.41	5.02	134.3	51.88	63.25	11.38	76.7	360
540	2737	28.2	97.0	2.72	5.12	134.4	54.43	64.95	10.52	74.7	388
541	3640	33.1	110	3.60	5.10	134.8	55.43	64.7	9.28	74.7	452
542	5085	39.1	130	5.03	5.04	134.3	54.48	62.35	7.87	75.9	527
543	6255	45.0	139	6.19	5.14	134.6	51.35	58.7	7.35	79.6	578
544	7855	47.8	164	7.77	5.10	134.3	54.1	60.33	6.23	77.1	635
545	8425	50.1	168	8.33	5.10	134.8	50.7	56.78	6.08	81.1	633
546	10000	53.8	186	9.91	5.02	134.3	49.48	54.98	5.50	82.1	670
547	11495	57.2	201	11.4	5.07	134.1	50.0	55.08	5.08	81.6	716
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
548	11325	69.8	162	11.2	4.06	126.3	50.9	57.25	6.35	72.2	1000
549	9980	67.4	148	9.88	4.11	126.3	51.38	58.3	6.91	71.5	967
550	9560	66.3	144	9.47	4.08	126.1	50.7	57.8	7.10	71.8	945
551	9225	65.8	140	9.13	4.06	126.3	50.5	57.83	7.33	72.1	938
552	7700	58.3	132	7.62	4.11	126.6	53.55	61.3	7.75	69.2	864
553	6525	54.8	119	6.46	4.11	126.4	50.58	59.2	8.62	71.5	788
554	5500	50.0	110	5.44	4.11	127.0	51.43	60.73	9.30	70.9	722
555	4060	42.2	96.4	4.02	4.13	127.1	51.90	62.55	10.65	69.9	618
556	2693	31.7	85.0	2.66	4.13	126.6	54.73	66.78	12.05	65.8	492
557	1212	17.5	69.5	1.20	4.13	127.0	53.88	68.63	14.75	65.7	273
558	11515	67.3	156	11.4	3.95	124.9	50.98	57.58	6.60	70.6	1076
559	10160	69.0	147	10.1	4.10	126.1	52 05	59.05	7.00	70.5	1008
560	7700	62.1	124	7.63	4.08	126.3	53.03	61.28	8.25	69.1	920
561	9260	64.7	143	9.17	4.03	125.4	56.5	63.68	7.18	65.8	1005
562	6830	59.8	114	6.76	4.00	125.1	49.08	58.1	9.02	71.5	862
563	5120	52.4	97.8	5.07	4.08	126.4	47.53	58.03	10.50	73.6	732
564	3980	42.0	94.7	3.94	4.13	126.7	53.9	64.73	10.83	67.4	640
565	2675	32.7	81.8	2.65	4.15	126.8	54.3	66.85	12.55	66.2	507
566	1250	18.1	69.1	1.24	4.15	127.0	53.98	68.83	14.85	65.6	283
567	11380	74.2	153	11.26	4.12	126.5	49.58	56.30	6.72	73.6	1040
568	9795	69.0	142	9.70	4.02	125.4	50.25	57.48	7.23	71.5	950
569	9225	65.3	141	9.12	4.02	125.0	50.38	57.68	7.30	71.0	947
570	7400	61.7	120	7.32	4.12	126.0	50.43	58.95	8.52	70.3	895
571	6340	59.2	107	6.27	4.11	126.5	49.83	59.38	9.55	71.9	842
572	4332	52.5	82.4	4.28	4.16	126.9	49.80	62.25	12.45	70.9	760
573	4475	52.5	85.2	4.43	4.11	126.0	49.8	61.83	12.03	70.2	769
574	11520	78.3	147	11.40	4.28	127.5	52.78	59.78	7.00	71.2	1132

TABLE 4. TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF CIRCULATING WATER VOLOCITY ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	t_1-t_0	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
575	9750	72.7	134	9.65	4.18	126.4	53.63	61.28	7.65	68.8	1080
576	8770	68.1	130	8.67	4.10	125.6	50.35	58.33	7.98	71.3	980
577	8620	66.6	130	8.52	4.20	126.4	51.7	59.63	7.93	70.7	963
578	7055	59.9	118	6.98	4.13	126 0	52.25	60.95	8.70	69.4	883
579	4060	43.3	93.6	4.01	4.13	126.1	51.45	62 4	10.95	68.7	647
580	5885	55.2	107	5.82	4.08	125.5	49.15	58.78	9.63	71.5	792
581	2690	32.9	81.7	2.67	4.23	126.6	49.68	62.25	12.57	69.6	487
582	872	12.9	67.7	0.86	4.26	127.4	51.85	67.03	15.18	68.0	195
583	11270	79.4	142	11.3	4.10	125.5	47.25	54.48	7.23	74 6	1090
584	11340	78.0	146	11.4	4.00	125.9	50.45	57.5	7.05	71.9	1110
585	9905	73.1	135	9 8	4.03	126.0	50.45	58.03	7.58	71.8	1056
586	8425	67.1	125	8.33	4.00	125.3	50.5	58.68	8.18	70.7	973
587	8390	67.6	124	8.30	3.97	124 8	47.13	55.4	8.27	73.5	943
588	6680	61.1	109	6.61	4.05	126.5	48.1	57.5	9.40	73.7	852
589	4060	44.1	92	4.01	4.07	126.0	50.63	61.8	11.17	69.8	648
590	5195	49.1	106	5.14	3.93	124.5	51.7	61.4	9.70	68.0	741
591	2767	32.6	84.8	2.74	4.10	126.6	53.15	65.25	12.10	67.4	497
592	2463	30.7	80.3	2.44	4.20	128.1	54.6	67.38	12.78	67.1	470
593	1743	22.9	76.2	1.65	4.12	126.5	55.68	69.15	13.47	64.1	350
594	986	13.8	71.5	0.98	4.15	126.3	57.25	71.6	14.35	61.9	229
595	11340	72.1	157	11.4	4.09	126.6	47.6	54.12	6.52	75.7	980
596	9985	68.0	147	9.88	4.09	126.8	47.7	54 68	6.98	75.6	922
597	8460	61.8	137	8.37	3.97	125.1	47.02	54.5	7.48	74.3	852
598	7665	59.2	129	7.59	4.12	127.1	48.55	56.48	7.93	74 6	818
599	6520	52.9	123	6.46	3.99	125.5	49.3	57.65	8.35	72 0	767
600	4890	45.7	107	4.84	4.07	126.4	49.48	59.08	9.60	72 1	652
601	8035	89.5	90.0	3.00	4.09	126.5	51.1	62.55	11.45	69 6	498
602	3375	35.2	96.0	3.34	3.99	125.1	51.82	62.52	10.7	67 9	531
603	1972	24.5	80.5	1.95	4.07	126.6	51.82	64.65	12.83	68.3	370
604	949	13.9	68 0	0.94	4.15	127.0	50.6	65.7	15.1	68.8	208
605	11075	139	79.5	10.95	18.0	187.0	47.08	59.45	12 37	133 7	1010
606	9835	133	73.9	9.74	17.98	186.8	46.68	59.98	13.3	133 5	968
607	8615	127	68.0	8.52	17.95	186.8	46.72	61.18	14 46	132 9	926
608	7895	121	65.4	7.82	18.05	187.1	46.8	61.83	15 03	133.8	876
609	5960	107	55.6	5.89	17.97	186.8	46.95	64.63	17.68	131.0	794
610	3830	82.6	46.4	3.79	17.92	186.7	47.38	68.58	21 2	128.7	623
611	2010	52.4	38.4	1.99	18.05	187.0	47.98	73.55	25.57	126.2	401
612	2313	59.8	38.7	2.29	18.0	186.8	48 0	73.38	25.38	126.1	459
613	873	25.3	34.5	0.86	17.95	187.0	49.10	77.53	28.43	123.7	198
614	11380	135	84.3	11.28	17.82	186.4	47.68	59.32	11.66	132.9	985
615	9985	127	78.6	9.87	17.99	186.9	48.18	60.68	12.5	132 5	929
616	8730	120	73.0	8.64	17.99	186.6	48.50	61.95	13.45	131.4	881
617	7855	115	68.4	7.77	17.82	186.0	48 25	62.62	14.38	130 6	854
618	6605	105	63.2	6.53	17.89	186.3	49.55	65.10	15.55	128.9	787
619	4970	88.8	56.0	4.92	17.97	186.6	48.10	65.68	17.58	129.7	665
620	3412	71.6	47.6	3.38	18.01	186.6	48.05	68.7	20.65	128.2	542
621	1479	39 6	37.4	1.46	18.19	187.3	48.70	75.03	26.33	125.4	306
622	2463	58 4	42 2	2 44	17.99	186.6	48.18	71.43	23.25	126.8	446

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
623	9000	59.2	163	8.91	2.65	111.6	46.98	53.35	6.37	60.9	940
624	9040	54.6	165	8.94	2.70	111.5	47.53	53.8	6.27	60.8	930
625	8840	44.3	199	8.75	2.70	111.3	61.05	66.25	5.20	47.6	967
626	8840	37.5	236	8.75	2.65	111.0	69.95	74.35	4.40	38.8	1000
627	8970	30.3	296	8.86	2.73	111.9	81.85	85.35	3.50	28.3	1108
628	9040	14.3	593	8.94	2.75	112.1	98.53	100.28	1.75	12.7	1233
638	8890	56.4	157	8.79	2.90	114.6	47.90	54.48	6.58	63.4	920
639	8840	44.4	199	8.75	2.90	114.1	62.83	68.03	5.20	48.7	945
640	8890	40.0	222	8.79	2.93	114.3	70.08	74.78	4.70	41.9	995
641	8970	34.4	261	8.86	2.93	115.1	79.58	83.55	3.97	33.5	1062
642	8810	24.8	354	8.72	2.95	114.4	90.13	93.10	2.92	22.8	1127
643	8810	17.0	518	8.72	2.95	116.0	99.4	101.4	2.00	15.6	1130
644	8620	8.50	1015	8.52	2.95	114.5	107.16	108.18	1.02	6.80	1290
645	8810	14.7	599	8.72	2.87	113.9	99.72	101.45	1.73	13.3	1145
646	8810	23.0	384	8.72	2.87	113.9	90.85	93.55	2.70	21.7	1095
647	8730	30.6	285	8.63	2.90	114.4	82.60	86.23	3.63	30.0	1055
648	8730	39.4	222	8.63	2.85	113.5	69.88	74.55	4.67	41.3	985
649	9000	57.1	158	8.91	3.00	115.4	48.58	55.15	6.57	63.5	930
650	9000	50.2	179	8.91	3.05	116.0	59.8	65.58	5.78	63.3	975
651	9000	41.0	220	8.91	2.97	114.5	70.53	75.25	4.72	41.6	1018
652	8925	32.1	278	8.82	3.00	114.6	81.35	85.08	3.73	31.4	1060
653	8810	25.0	353	8.72	3.03	115.1	90.00	92.93	2.93	23.7	1088
654	8925	17.2	518	8.82	3.05	117.4	100.98	102.98	2.00	15.4	1158
655	8890	4.30	2070	8.79	3.04	115.5	111.88	112.38	0.50	3.30	1342
656	8925	4.40	2030	8.82	3.04	115.0	111.13	111.64	0.51	3.60	1263
657	8925	15.9	560	8.82	3.02	115.0	100.33	102.18	1.85	13.8	1193
658	8925	56.5	158	8.82	2.98	113.8	49.8	56.35	6.55	60.7	963
659	8810	48.5	182	8.72	3.03	114.5	61.18	66.88	5.70	50.5	993
660	8970	42.2	212	8.86	3.05	114.8	69.83	74.75	4.92	42.5	1036
661	8840	32.2	274	8.75	3.13	115.1	81.40	85.13	3.73	31.8	1050
662	8840	24.1	366	8.75	3.13	115.0	90.62	93.45	2.83	23.0	1088
663	8810	14.7	598	8.72	3.13	115.3	101.35	103.08	1.73	13.1	1163
664	8730	4.90	1786	8.63	3.14	115.3	111.07	111.65	0.58	3.90	1295
665	8970	5.02	1786	8.86	3.14	115.1	111.10	111.68	0.58	3.70	1403
666	8840	15.2	581	8.75	3.14	115.3	101.34	103.12	1.78	13.1	1200
667	9080	24.8	366	8.98	3.09	115.4	90.75	93.68	2.83	23.1	1113
668	8730	32.6	267	8.63	3.09	115.0	80.35	84.23	3.88	32.7	1035
669	8810	40.2	219	8.72	3.02	114.8	71.12	75.85	4.73	41.3	1008
670	8810	48.3	182	8.72	3.05	115.0	61.38	67.05	5.68	50.8	984
671	8970	7.90	1138	8.86	2.86	114.5	107.27	108.18	0.91	6.80	1200
672	8810	8.40	1057	8.72	2.88	114.4	107.27	108.25	0.98	6.60	1305
673	9000	4.80	1881	8.91	2.90	114.9	110.90	111.45	0.55	3.70	1335
674	8810	4.40	1981	8.72	2.92	114.7	111.28	111.82	0.54	3.15	1510

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr. —Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
675	8970	6.70	1345	8.86	2.92	114.0	108.51	109.28	0.77	5.40	1275
676	8810	10.8	815	8.72	2.93	114.6	104.38	105.65	1.27	9.60	1165
678	8840	8.00	1101	8.75	3.05	114.7	107.99	108.93	0.94	6.20	1342
679	8890	12.1	735	8.79	3.02	113.6	102.79	104.2	1.41	10.2	1228
680	8730	12.6	690	8.64	3.10	115.3	103.88	105.38	1.50	10.7	1225
681	8970	7.50	1190	8.86	3.10	115.1	109.06	109.93	0.87	5.60	1367
682	8770	4.30	2030	8.68	3.15	115.4	111.94	112.45	0.51	3.20	1395
683	8890	7.90	1125	8.80	3.15	115.1	108.86	109.78	0.92	5.80	1405
686	6185	4.80	1294	6.12	3.10	114.6	109.80	110.6	0.80	4.40	1123
687	6030	13.9	435	5.97	3.10	114.3	99.45	101.83	2.38	13.7	1047
688	5995	21.1	284	5.93	3.04	113.4	89.83	93.48	3.65	21.7	1007
689	5995	28.6	209	5.93	3.12	115.0	81.10	86.05	4.95	31.4	945
690	5955	35.6	167	5.90	3.10	114.3	69.78	75.98	6.20	41.4	892
691	6185	42.4	146	6.12	3.10	114.2	60.73	67.83	7.10	49.9	868
692	6220	47.9	130	6.16	3.10	115.0	49.70	57.68	7 98	61.3	812
693	6300	48.5	130	6.24	3.12	114.5	49.53	57.5	7.97	61.0	823
694	6220	41.5	150	6.16	2.95	114.3	60.80	67.7	6.90	50.0	858
695	6185	36.2	171	6.12	2.95	115 3	70.25	76.3	6.05	42.0	891
696	6262	29.7	211	6.20	2.95	115 5	80.18	85.10	4.92	32.9	935
697	6340	22.0	288	6.28	2.97	114.5	89.95	93.55	3.60	22.7	1005
698	6370	13.2	481	6.31	2.95	114.5	100.38	102.53	2.15	13.0	1055
699	6185	4.30	1480	6.12	2.95	114.5	110.78	111.48	0.70	3.40	1272
700	3640	3.90	1262	3.61	2.95	114.5	110.33	111.15	0.82	3.80	786
701	3718	9.20	403	3.68	2.93	113.3	99.08	101.65	2.57	12.9	741
702	3415	10.3	233	3.38	3.08	114.3	91.33	95.78	4.45	20.7	733
703	3792	21.6	176	3.76	3.03	113.5	79.65	85.55	5.90	30.9	723
704	3718	26.5	140	3.68	3.08	114.1	71.05	78.45	7.40	39.3	700
705	3718	30.2	123	3.68	3.08	113.6	62.35	70.78	8.43	47.0	665
706	3680	33.9	108	3.64	3.08	114.0	53.73	63.28	9.55	55.5	632
707	3680	34.0	108	3.64	3.08	114.0	52.93	62.50	9.57	56.1	627
708	3562	29.8	120	3.53	3.02	113.5	59.80	68.45	8.65	49.4	625
709	3562	25.0	142	3.53	3.02	113.8	70.90	78.18	7.28	39.3	660
710	3562	20.6	173	3.53	3.03	114.0	80.25	86.23	5.98	30.8	693
711	3562	14.8	241	3.53	3.06	114.1	90.85	95.15	4.30	21.1	722
712	3562	8.40	423	3.53	2.96	113.3	100.30	102.75	2.45	11.8	740
713	3600	4.00	901	3.57	3.08	115.4	109.75	110.9	1.15	5.10	812
714	2028	21.0	97.0	2.01	2.81	112.4	51.78	62.48	10.7	55.3	392
715	1859	17.6	105	1.83	2.91	113.8	61.48	71.30	9.82	47.6	383
716	1859	14.9	124	1.83	2.86	113.0	71.08	79.4	8.32	37.7	410
717	1820	12.4	146	1.80	2.93	113.5	79.35	86.42	7.07	30.6	420
718	1915	8.80	217	1.90	2.86	112.6	90.50	95.28	4.78	19.7	478

TABLE 5 TESTS OF HEAT TRANSFER THROUGH CONDENSER TUBES—Con.

MADE TO DETERMINE EFFECT OF VARIATIONS OF MEAN TEMPERATURE DIFFERENCE ON HEAT TRANSFER

Test Number	Circulating Water Per Hour, Lb.	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
No.	Q	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ_m	U
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.											
719	2160	5.70	376	2 14	2.96	113.8	100.48	103.23	2.75	11.9	500
720	2160	1.90	1114	2.14	2.93	113.8	110.30	111.23	0.93	3.10	650
721	2085	1.90	1068	2.07	2.86	112.8	109.18	110.15	0.97	3.2	632
722	2102	6.10	348	2.09	2.89	112.9	99.15	102.13	2.98	12.3	510
723	1952	10.1	193	1.93	2.96	113.9	88.67	94.05	5.38	22.5	467
724	2122	14.1	151	2.10	2.91	113.1	80.58	87.43	6.85	29.1	500
725	2141	22.1	96.8	2.12	2.89	113.6	63.5	64.2	10.7	54.7	418
726	2045	18.9	108	2.03	2.89	113.5	61.85	71.4	9.55	46.9	433
727	1895	15.8	120	1.87	2.99	114.6	71.03	79.68	8.65	39.2	418

TABLE 6 TESTS OF HEAT TRANSFER

	Test Number	Circulating Water Used Per Hour, Lb.	Steam Condensed Per Hour, Lb.
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	728	8925	32.6
	729	8730	33.5
Copper Tube, 1 In. Outside Diameter, 16 B.W.G.	730	9080	33.6
	731	9150	33.1
Cupro-Nickel Tube, 1 In. Outside Diameter, 18 B.W.G.	732	8810	26.1
	733	9000	26.9
Old Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	733A	8970	19.7
	734	8770	19.1
Aluminum-Bronze Tube, 1 In. Outside Diameter, 18 B.W.G.	735	9040	30.4
	736	8970	30.2
Monel Tube, 1 In. Outside Diameter, 18 B.W.G.	737	9000	24.5
	738	9040	25.3
Aluminum-Lined Tube, 1 In. Outside Diameter, 18 B.W.G.	739	8840	33.5
	740	9080	33.9
Shelby Steel Tube, 1 In. Outside Diameter, 18 B.W.G.	741	9040	22.8
	742	8840	22.0
Admiralty Lead-Lined, 1 In. Outside Diameter, 0.088 In. Thick	743	8650	27.6
	744	8810	27.3
Admiralty-Oxidized, 1 In. Outside Diameter, 18 B.W.G.	745	8890	30.8
	746	9040	32.0
Zinc Tube, 1 In. Outside Diameter, 18 B.W.G.	747	8925	26.0
	748	8970	25.7
Tin Tube, 1 In. Outside Diameter, 0.055 In. Thick	749	8840	27.7
	750	8970	27.2
Admiralty Tube, 1 In. Outside Diameter, 18 B.W.G.	751	9080	105
	752	8970	101
	753	8890	93.1
	754	8925	82.7
	755	9120	70.5
	756	8770	62.0
	757	8890	104
	758	8620	95.7
	759	8840	89.0
	760	8770	80.5
	761	8730	70.5
	762	8890	59.8
Copper Tube, 1 In. Outside Diameter, 16 B.W.G.	763	8925	51.8
	764	9040	71.1
	765	9080	99.4
	766	8970	117
	767	9000	138
Admiralty, Vulc. Inside, 1 In. Outside Diameter, 18 B.W.G.	768	8730	177
	769	8730	186
Admiralty, Vulc. Both Sides, 1 In. Outside Diameter, 18 B.W.G.	770	8770	6.4
	771	9040	6.6

THROUGH CONDENSER TUBES

Ratio of Water to Steam	Velocity of Water in Tube, Ft. Per. Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.—Arith.	B.t.u. Per Sq. Ft. Per Hour Per Deg. Mean Temperature Difference
274	8.83	2.81	114.4	85.75	89.53	3.78	26.8	1257
260	8.62	2.86	115.7	85.50	89.48	3.98	28.2	1232
270	9.38	2.93	114.7	85.40	89.23	3.83	27.4	1267
276	9.42	2.91	114.3	84.78	88.53	3.75	27.6	1243
337	8.71	2.99	114.9	86.03	89.1	3.07	27.3	988
334	8.90	2.93	114.1	85.38	88.48	3.10	27.2	1024
456	8.87	2.96	114.8	84.58	86.85	2.27	29.1	703
460	8.67	2.96	114.6	85.45	87.70	2.25	28.0	705
298	8.94	3.12	116.0	85.45	88.93	3.48	28.8	1090
298	8.87	3.05	114.9	84.62	88.10	3.48	28.5	1092
368	8.90	2.99	113.8	85.18	88.00	2.82	27.2	932
357	8.94	2.99	114.5	84.92	87.82	2.90	28.1	932
264	8.99	2.96	115.3	84.90	88.83	3.93	28.4	1223
268	9.21	2.96	115.0	85.28	89.15	3.87	27.8	1262
395	8.94	3.07	115.6	84.88	87.50	2.62	29.4	805
401	8.75	2.99	115.1	85.60	88.18	2.58	28.2	808
309	10.00	3.01	115.1	85.10	88.45	3.35	28.3	1023
322	10.20	2.99	114.9	85.52	88.75	3.23	27.8	1022
288	8.79	3.07	115.3	85.38	88.98	3.60	28.1	1136
282	8.94	3.04	115.0	85.15	88.82	3.67	28.0	1183
343	8.83	3.07	115.6	85.98	89.00	3.02	28.1	958
348	8.87	3.07	115.0	85.48	88.45	2.97	28.0	948
318	8.94	3.14	115.9	86.00	89.25	3.25	28.3	1015
329	9.07	3.07	115.0	85.48	88.63	3.15	27.9	1009
86.6	8.98	9.70	161.3	53.30	64.88	11.58	102.2	1027
89.0	8.87	9.68	160.3	53.55	64.83	11.28	101.1	1000
95.5	8.79	9.68	160.0	63.98	74.48	10.5	90.8	1027
108	8.83	9.57	159.3	77.93	87.2	9.27	76.6	1078
129.4	9.02	9.72	160.5	93.00	100.75	7.75	63.6	1108
141.2	8.67	9.75	160.6	101.80	108.9	7.10	55.2	1127
85.4	8.79	9.84	161.3	55.33	67.08	11.75	100.1	1040
90.0	8.52	9.78	161.1	62.50	73.65	11.15	93.0	1033
99.4	8.75	9.85	161.0	72.60	82.7	10.1	83.3	1070
109	8.68	9.71	160.3	81.25	90.45	9.2	74.4	1083
124	8.64	9.73	160.0	92.93	101.03	8.10	63.0	1120
149	8.79	9.75	160.5	106.50	113.25	6.75	50.7	1182
172	9.25	3.02	114.9	56.68	62.7	6.02	54.2	992
127	9.36	4.97	134.0	56.63	64.68	8.05	73.3	1005
91.4	9.37	9.82	160.7	56.85	67.83	10.98	98.3	1015
76.4	9.30	14.79	178.1	56.50	69.45	12.95	115.1	1007
65.1	9.34	22.52	197.0	56.65	71.65	15.00	132.8	1017
49.2	8.65	3.00	117.8	85.95	88.05	2.10	30.8	596
47.0	8.65	3.00	117.2	84.45	86.65	2.20	31.6	607
1380	8.68	3.02	115.7	85.48	86.23	0.75	30.0	219
1380	8.94	3.07	115.9	85.95	86.70	0.75	29.7	227

TABLE 7 CONDENSER TESTS *

MADE ON A CYLINDRICAL SURFACE CONDENSER CONTAINING 300 SQ. FT. OF TUBE SURFACE

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tubes, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise, Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Difference Per Hour
No.	W	R	V_w	p	t_s	t_0	t_1	$t_1 - t_0$	θ	$l \div d$	U
1	1504	122.0	0.952	2.15	106.7	85.0	93.0	8.0	17.4	15.657	281
2	1484	101.2	0.780	2.33	107.7	85.6	95.2	9.6	16.8	15.657	286
3	1495	80.3	0.620	2.5	110.5	85.5	98.0	12.5	18.05	15.657	275
4	1503	61.1	0.476	3.08	117.5	86.0	103.0	17.0	21.95	15.657	237
5	1469	51.5	0.393	3.42	121.0	85.0	107.0	22.0	23.32	15.657	237
6	1552	107.0	0.862	2.0	104.7	80.0	90.0	10.0	19.27	15.657	293
7	1487	95.7	0.738	2.11	104.3	79.2	91.8	12.6	18.05	15.657	332
8	1533	83.0	0.655	2.31	107.4	80.09	94.6	14.51	19.13	15.657	321
9	1497	61.4	0.478	2.73	112.8	81.6	98.1	16.5	21.95	15.657	224
10	1537	49.25	0.393	3.19	117.8	80.0	100.9	20.9	25.98	15.657	199
11	1590	114.0	0.942	1.82	100.0	74.5	83.5	9.0	20.7	15.657	263
12	1542	78.0	0.624	2.09	104.8	75.0	88.5	13.5	22.35	15.657	242
13	1595	60.2	0.498	2.45	109.2	75.1	93.9	18.8	23.42	15.657	245
14	1514	39.65	0.312	3.29	119.6	74.97	101.4	26.43	29.5	15.657	180
15	1600	103.5	0.861	1.58	94.2	70.0	80.0	10.0	18.73	15.657	293
16	1502	69.5	0.547	1.93	101.0	70.0	85.4	15.4	22.45	15.657	238
17	1529	49.5	0.393	2.55	113.3	70.0	92.7	22.7	30.6	15.657	187
18	1510	39.8	0.309	3.12	117.5	70.0	98.5	28.5	31.1	15.657	183
19	1560	106.0	0.860	1.23	88.7	65.0	74.5	9.5	18.5	15.657	283
20	1601	66.0	0.550	1.91	103.0	65.05	81.4	16.35	29.05	15.657	198
21	1520	49.7	0.393	2.32	111.9	64.2	86.7	22.5	35.35	15.657	161
22	1495	40.2	0.312	2.93	115.5	65.06	91.8	26.74	35.5	15.657	151
23	2050	96.8	1.030	2.48	108.6	85.0	96 4	11.4	17.28	15.657	436
24	1993	79.5	0.812	2.8	113.34	84.64	98.8	14.16	20.83	15.657	335
25	2054	59.2	0.631	3.36	118.9	85.04	103.96	18.92	23.15	15.657	327
26	1998	49.5	0.875	3.67	122.5	84.9	108.32	23.42	24.03	15.657	322
27	1964	101.0	1.030	2.28	106.6	81.1	92.9	11.8	19.0	15.657	412
28	1983	80.0	0.825	2.44	108.3	80.9	95.5	14.6	19.19	15.657	402
29	2038	58.93	0.622	2.97	114.3	80.1	99.0	18.9	23.5	15.657	322
30	2068	47.7	0.512	3.45	119.5	80.0	101.6	21.6	27.32	15.657	260
31	1908	95.0	0.940	2.14	103.3	75.0	87.2	12.2	21.65	15.657	341
32	1993	79.5	0.823	2.25	107.0	75.7	90.7	15.0	23.0	15.657	345
33	1986	49.75	0.510	2.82	114.5	75.0	98.0	23.0	26.35	15.657	288
34	2009	39.1	0.407	3.51	120.3	75.0	103.0	28.0	29.1	15.657	246
35	2016	111.5	1.170	1.64	95.0	70.2	78.8	8.6	20.2	15.657	320
36	2076	76.0	0.825	2.03	104.4	70.3	83.8	13.5	26.8	15.657	265
37	2017	66.8	0.700	2.1	105.5	70.3	87.3	17.0	25.8	15.657	297
38	1992	60.25	0.622	2.08	103.9	68.5	86.15	17.65	25.6	15.657	276
39	1963	50.25	0.512	2.53	110.0	70.0	91.4	21.4	27.95	15.657	252
40	2029	38.7	0.408	3.27	119.4	70.0	98.3	28.3	33.3	15.657	221
41	2106	94.2	1.030	1.52	92.2	65.0	76.0	11.0	21.2	15 657	343

* Tests made by R. W. Allen and published in Proceedings, Inst. of C. E., Feb. 28, 1905

TABLE 7 CONDENSER TEST—Con.

MADE ON A CYLINDRICAL SURFACE CONDENSER CONTAINING 300 SQ. FT. OF TUBE SURFACE

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Difference Per Hr.
N .	W	R	V_W	p	t_s	t_0	t_1	$t_1 - t_0$	θ	$l \div d$	U
42	2008	79.0	0.824	1.70	96.0	65.0	78.3	13.3	23.8	15.657	296
43	2154	55.73	0.623	2.10	103.5	65.0	82.7	17.7	28.78	15.657	246
44	1932	40.7	0.408	2.89	114.0	65.0	90.7	25.7	34.63	15.657	195
45	2440	121.0	1.535	2.48	107.7	85.0	92.7	7.7	18.6	15.657	407
46	2460	91.25	1.161	2.72	111.7	85.0	95.0	10.0	21.3	15.657	351
47	2520	78.8	1.032	2.98	113.5	84.75	96.8	12.05	22.2	15.657	360
48	2428	60.3	0.764	3.45	119.0	84.6	100.8	16.2	25.41	15.657	311
49	2520	117.3	1.532	2.15	103.2	80.1	88.6	8.5	18.55	15.657	453
50	2600	94 25	1.273	2.38	106.3	80.0	90.5	10.5	20.62	15.657	417
51	2580	77.0	1.044	2.71	110 8	80.5	94 1	13.6	22.85	15.657	394
52	2500	60.0	0.780	3.09	116.0	80.0	96.7	16.7	26.83	15.657	310
53	2580	118.5	1.589	1.84	99.7	75.0	83.0	8.0	20.4	15.657	400
54	2460	99.7	1.274	2 06	102.0	75.25	85.0	9.75	21.53	15.657	370
55	2484	80.0	1.032	2.33	106.4	74.9	87.4	12.5	24.75	15.657	339
56	2565	58.5	0.778	2.96	112.5	75.0	93.0	8 0	12.25	15.657	327
57	2520	39.1	0.512	3.88	123.6	75.0	100.3	25.3	34.42	15.657	241
58	2620	115.3	1.571	1.72	95.0	70.1	78.7	8 6	20 25	15.657	427
59	2424	101.0	1.272	1.81	98.2	69.7	79.0	9.3	23.6	15.657	322
60	2520	78.8	1.032	2.15	103.3	70.0	83.0	13.0	26.3	15.657	327
61	2468	40.0	0.512	3.54	120.2	70.0	95.7	25.7	35.8	15.657	236
62	2445	121.0	1.538	1.40	90.5	65.1	73.0	7.9	21.25	15.657	322
63	2400	93.5	1.165	1.65	94.2	64.7	74.7	10 0	24 2	15.657	309
64	2430	61.75	0.778	2.17	104.7	65.0	83.0	18.0	29.8	15.657	302
65	2515	39.3	0.512	3.22	117.2	65.0	91.0	26.0	37.75	15.657	228
66	2916	105.0	1.590	2.70	110.6	85.0	94.6	9.6	20.41	15.657	482
67	3041	80.5	1.270	2.97	113.6	85.0	97.0	12.0	22.08	15.657	438
68	2964	69.7	1.073	3.30	117.9	85.0	99.0	14.0	25.25	15.657	382
69	2968	58.5	0.901	3.68	121.8	84.9	102.2	17.3	27.39	15.657	366
70	3012	98.5	1.538	2.40	107.2	80.1	90.0	9.9	21.77	15.657	448
71	2960	84.75	1.303	2.60	109.0	80.0	91.6	11.6	22.75	15.657	427
72	2952	59.0	0.905	3.28	117.0	80.0	96.7	16.7	27.9	15.657	348
73	3048	106.5	1.689	1.94	101.0	75.0	83.0	8.0	21.8	15.657	397
74	3015	98.5	1.541	2.09	102.7	75.0	84.2	9.2	22.8	15.657	400
75	2970	81.7	1.260	2.28	106.2	75.0	87.0	12.0	24.4	15.657	398
76	2940	61.5	0.938	2.66	110.7	75.0	91.5	16.5	26.58	15.657	376
77	3015	49.75	0.778	3.34	118.75	75.0	96.0	21.0	32.1	15.657	326
78	3012	107.8	1.690	1.78	97.1	70.3	79.1	8.8	22.02	15.657	434
79	3000	99.0	1.538	1.83	99.1	70.25	80.25	10.0	23.5	15.657	421
80	2970	61.0	0.942	2.56	111.0	70.0	86.7	16.7	32.0	15.657	315
81	3171	37.9	0.624	3.82	122.5	69.7	96.2	26.5	38.1	15.657	277
82	2970	90.7	1.400	1.70	95.6	64.6	75.2	10.6	25.3	15.657	376
83	2965	69.5	1.070	2.03	101.3	65.0	79.5	14.5	28.35	15.657	351
84	3077	48.75	0.770	2.74	111.6	65.0	86.4	21.4	34.78	15.675	307

TABLE 8 HEATER TESTS *

Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Total Tube Surface' Sq. Ft.	Ratio of Length in Ft. to Diameter in In.	Velocity of Water in Tubes, Ft. Per Sec.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\log_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour	Remarks
No.	Q	R	S	$l \div d$	V_w	t_s	t_0	t_1	$t_1 - t_0$		θ	U	
1	176	20.0	0.1964	3.00	0.867	212	47.8	96.7	48.9	0.3528	138.5	314	Stanton One copper tube, 0.5 in. outside diameter, 19 B.W.G., 18 in. long, tube in vertical position. Water circulated up in Tests 1–4, down in Tests 5–8
2	357	32.1	0.1964	3.00	1.76	212	47.8	78.0	30.2	0.2045	147.7	376	
3	464	36.5	0.1964	3.00	2.29	212	46.7	73.2	26.5	0.1747	151.8	411	
4	806	48.8	0.1964	3.00	3.97	212	54.3	74.1	19.8	0.1336	148.2	547	
5	176	15.5	0.1964	3.00	0.867	212	47.8	110.3	62.5	0.4811	130	430	
6	357	27.5	0.1964	3.00	1.76	212	47.8	83.0	35.2	0.2422	145.1	439	
7	464	31.4	0.1964	3.00	2.29	212	46.7	77.5	30.8	0.2070	148.7	489	
8	806	46.9	0.1964	3.00	3.97	212	54.3	74.9	20.6	0.1398	147.2	573	
9	702	11.22	1.065	7.23	1.33	255	58.0	140	82.0	0.5377	153.2	356	Nichols One brass tube, 0.75 in. outside diameter, 18 B.W.G., 65 in. long. Tube vertical in Tests 9–11, horizontal in Tests 12–14. Water ran up in Tests 9–11
10	2421	26.4	1.065	7.23	4.60	255	58.0	93.5	35.5	0.1988	178.6	452	
11	3393	34.7	1.065	7.23	6.44	256	58.0	85.0	27.0	0.1467	184	467	
12	675	8.75	1.065	7.23	1.28	253	57.8	165	107.2	0.7975	134.5	505	
13	2670	21.8	1.065	7.23	5.06	253	58.0	101	43.0	0.2484	173	622	
14	3612	25.6	1.065	7.23	6.85	254	58.0	94.5	36.5	0.2058	177.4	698	

15	1216	8.12	13.09	16.0	0.373	212	74.0	193	119	1.9831	60	184	Hepburn Copper tubes, 1.25 in. outside diameter, 18 B.W.G., 20 in. long. Tubes horizontal. Corrugated tubes in Tests 24–27. Tests 20–23, 1 tube: Tests 15, 16, 26, 27, 2 tubes Tests 17–19, 24–25, 6 tubes
16	1342	9.11	13.09	16.0	0.412	212	74.0	180	106	1.4609	72.5	150	
17	2870	10.07	39.27	16.0	0.294	212	74.0	170	96.0	1.1894	80.7	86.9	
18	2292	7.87	39.27	16.0	0.222	212	72.0	195	123	2.1090	58.3	123	
19	1548	7.44	39.27	16.0	0.158	211	74.0	204	130	2.9745	43.7	117	
20	3082	9.73	6.045	16.0	1.89	217	71.0	170	99	1.1346	87.1	580	
21	2464	9.64	6.045	16.0	1.51	216	72.0	172	100	1.1860	84.3	484	
22	3708	10.60	6.045	16.0	2.275	216	71.0	162	91	0.9877	92.1	606	
23	1084	9.47	6.045	16.0	0.666	214	72.0	174	102	1.2669	80.6	227	
24	3930	5.93	45.2	16.0	0.402	211	41.0	204	163	3.1905	51.1	277	
25	4006	5.89	45.2	16.0	0.410	212	40.0	204	164	3.1294	52.4	277	
26	4440	7.53	15.07	16.0	1.361	215	67.0	195	128	2.0015	63.9	591	
27	3530	7.20	15.07	16.0	1.082	214	66.0	200	134	2.3582	56.9	542	
28	2799	6.65	54.2	3.333	0.048	215	62.0	207	145	2.9502	49.1	152	Hildreth Corrugated copper tubes, 1.5 in. outside diameter, 18 B.W.G. Vertical position, water circulated up. Tests 28–36, 24 tubes, 5 in. long. Tests 37–44, 36 tubes, 6 ft. 2 in. long.
29	3965	6.92	54.2	3.333	0.068	215	62.0	201.3	139.3	2.4132	57.8	176	
30	5223	7.36	54.2	3.333	0.090	215	62.0	193	131	1.9402	67.5	187	
31	5162	7.30	54.2	3.333	0.089	215	62.0	194.3	132.3	2.0001	66.6	189	
32	2558	6.58	54.2	3.333	0.044	215	62.0	208.5	146.5	3.1591	46 6	148	
33	3069	6.67	54.2	3.333	0.053	215	62.0	206.5	144.5	2.8903	50	164	
34	3993	6.92	54.2	3.333	0.069	215	62.0	201.3	139.3	2.4123	57.8	177	
35	4950	7.25	54.2	3.333	0.086	215	62.0	195.3	133.3	2.0503	65.1	187	
36	4805	7.15	54.2	3.333	0.083	215	62.0	197	135	2.1401	63.1	190	
37	1215	6.46	100.	4.10	0.014	215	62.0	211.3	149.3	3.7220	40.1	45.7	
38	3296	6.47	100.	4.10	0.038	215	62.0	211	149	3.6433	40.9	120	
39	3807	6.51	100.	4.10	0.044	215	62.0	210	148	3.4209	43.2	130	
40	4468	6.60	100.	4.10	0.0513	215	62.0	208	146	3.0842	47.3	138	
41	5879	6.75	100.	4.10	0.0675	215	62.0	205	143	2.7278	52.4	160	
42	6387	6.84	100	4.10	0.0735	215	62.0	203	141	2.5447	55.4	162	
43	7128	6.95	100.	4.10	0.082	215	62.0	200.8	138.8	2.3768	58.5	169	
44	7869	7.08	100.	4.10	0.091	215	62.0	198	136	2.1972	62.0	173	
45	4111	5.77	33.35	16.4	0.567	219	45.0	211.8	166.8	3.1201	53.4	385	Richter 3 corrugated copper tubes, 15 in. outside diameter, 18 B.W.G., 24 ft. 8 in. long. Horizontal.
46	5231	5.54	33 35	16.4	0.722	229	43.0	215.2	172.2	2.5810	66.7	406	
47	3936	5.22	33.35	16.4	0.543	233	45.0	227	182	3.4442	52.8	407	

* Tests made by H. L. Hepburn and published in *Power*. December 1901

TABLE 9 HEAT TRANSMISSION TESTS*

Table Number	Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Velocity, Ft. Per Sec.	Absolute Pressure, Lb. Per Sq. In.	Steam Temperature, Deg. Fahr.	Water Temperature, In, Deg. Fahr.	Water Temperature Out, Deg. Fahr.	Rise of Temperature, Deg. Fahr.	$\log_e \frac{t_s - t_0}{t_s - t_1}$	Mean Difference of Temperature, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour.
No.	N c.	Q	R	V_w	p	t_s	t_0	1	$t_1 - t_0$		θ	U
Brass Tube 37.0 In. Long, 1.93 In. Outside Diameter, 0.0788 In. Thick, Enclosing a Closed Tube 1.515 In. Outside Diameter. Outer Tube Water Area, 0.00467 Sq. Ft. Surface, 1.56 Sq. Ft. $\frac{l}{d} = 1.6$												
Table 2	4	305	12.1	0.29	14.7	212	79.0	159.0	80.0	0.9203	86.9	180
	5	305	11.96	0.29	14.7	212	78.5	159.3	80 8	0.9282	87.0	181
	6	468	17.0	0.446	14.7	212	99.0	146.7	56.7	0.6259	90.6	188
	7	463	17.3	0.44	14.7	212	90.0	146.0	56.0	0.6152	91.0	183
	8	832	24.6	0.793	14.7	212	98.6	137.9	39.3	0.4253	92.4	227
	9	868	24.5	0.826	14.7	212	98 3	137.7	39.4	0.4253	92.7	236
	10	2660	36.6	2.63	14.7	212	106.4	132.8	26.4	0.2867	92.1	488
	11	2605	36.3	2.49	14.7	212	106.2	132.8	26.6	0.2897	91.9	483
	11*a*	4060	46.2	3.87	14.7	212	106 4	127.3	20.9	0.2199	95.1	572
	11*b*	5740	62.0	5.47	14.7	212	109 0	124.6	15.6	0.1655	94.3	609
	11*c*	5840	57.5	5.56	14.7	212	106.2	123.0	16.8	0.1722	97.5	645
	11*d*	5975	74.4	5.69	14.7	212	123.4	136.4	13.0	0.1578	82.4	605
Table 3	12	1026	113.8	0.976	14.7	212	192.0	200.5	8.5	0.5539	15.3	368
	13	1026	94.8	0.976	14.7	212	187.5	197.7	10.2	0.5385	18.9	355
	14	1037	50.8	0.987	14.7	212	164.0	183.0	19.0	0.5032	37.8	334
	15	1022	33.6	0.974	14.7	212	134.3	163.0	28.7	0.4605	62.3	302
	16	1050	28.1	1.00	14.7	213	118.1	152.4	34.3	0.4479	76.6	302
	17	1049	25.0	1.00	14.7	213	104.0	142.5	38.5	0.4356	88.4	293
	18	1037	24.7	0.987	14.7	213	96.0	135.1	39.1	0.4055	96.5	269
	19	1022	23.5	0.974	14.7	213	84.0	125.1	41.1	0.3847	106.8	252
	20	1050	20.7	1.00	14.7	213	60.6	107.1	46.5	0.3646	127.4	246

Table 4	21	2250	144.3	2.14	14.7	212	191.2	197.9	6.7	0.3887	17.2	562
	22	2207	142.1	2.10	14.7	212	190.2	197.0	6.8	0.3730	18.2	529
	23	2107	122.3	2.01	14.7	212	186.9	194.8	7.9	0.3784	20.8	513
	24	2107	57.9	2.01	14.7	212	159.0	175.7	16.7	0.3784	44.0	513
	25	2098	59.3	2.00	14.7	212	158.5	174.8	16.3	0.3633	44.9	488
	26	2098	42.6	2.00	14.7	212	131.3	154.0	22.7	0.3300	68.8	444
	27	2110	34.8	2.10	14.7	212	105.0	132.8	27.8	0.3001	92.7	405
	28	2115	34.6	2.13	14.7	212	87.3	115.2	27.9	0.2531	110.2	343
	29	2098	28.5	2.00	14.7	212	49.6	83.5	33.9	0.2335	145.1	314
Table 5	30	3400	261.0	3.24	14.7	212	195.5	199.2	3.7	0.2546	14.51	555
	31	3370	276.0	3.21	14.7	212	195.5	199.0	3.5	0.2390	14.62	517
	32	3340	241.5	3.18	14.7	212	188.8	192.8	4.0	0.1894	21.1	406
	33	3450	56.8	3.28	14.7	212	141.0	158.0	17.0	0.2723	62.4	603
	34	3424	42.9	3.26	14.7	212	110.3	132.8	22.5	0.2484	90.5	547
	35	3395	34.0	3.23	14.7	212	49.1	77.5	28.4	0.1906	149.0	414
Table 6	36	5415	312.0	5.16	14.7	212	193.5	196.6	3.1	0.1823	17.0	633
	37	5480	84.8	5.22	14.7	212	161.5	172.9	11.4	0.2554	44.6	887
	38	5525	60.4	5.26	14.7	212	127.0	143.0	16.0	0.2078	77.0	737
	39	5415	42.6	5.16	14.7	212	49.3	72.0	22.7	0.1484	153.0	515
	40	5560	45.1	5.30	14.7	212	49.3	70.7	21.4	0.1398	153.0	498
Table 11	72–73	4710	37.3	4.48	14.7	212	43.5	69.4	25.9	0.1663	155.7	503
	74	4710	34.5	4.48	17.5	221	44.2	72.0	27.8	0.1697	164.0	512
	75	4710	31.3	4.48	23.0	236	44.2	74.5	30.3	0.1714	176.8	518
	76–77	4710	26.0	4.48	34.2	257.9	43.6	79.5	35.9	0.1831	196.0	554
	78–79	4630	25.3	4.41	39.3	266	43.3	79.9	36.6	0.1747	209.5	518
Table 12	81	2055	15.8	1.96	32.3	254.1	43.7	103.0	59.3	0.3300	179.6	435
	82	2055	16.8	1.96	28.8	248	43.7	99.5	55.8	0.3193	174.3	421
	83	2055	18.6	1.96	23.0	236	43.7	94.7	51.0	0.3075	166.0	404
	84	2055	21.6	1.96	17.5	221	43.3	87.8	44.5	0.2860	155.5	377
	85	2100	24.7	2.00	14.7	212	43.7	82.8	39.1	0.2639	148.1	355
	86	2067	26.6	1.97	13.2	206.6	43.7	80.2	36.5	0.2538	144.0	336
	87	2080	26.8	1.98	12.5	203.9	43.7	79.9	36.2	0.2561	141.1	342
	88	2055	31.5	1.96	9.4	190.4	43.7	74.9	31.2	0.2390	130.8	314

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* Tests made by Gustav Hagemann and published in the Proceedings, Inst.C.E., vol. 22, 1883

TABLE 10 CONDENSER TUBE

Test Number	Steam Condensed Per Hour	Ratio of Water to Steam $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per. Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg Fahr.
No.	W	R	V_w	p	t_s	t_p	t_0	t_p
1	2.374	41.1	0.057	1.56	93.3	91.55	41.33	68.40
2	5.818	17.0	0.58	5.00	134.	131.5	41.33	104.7
3	18.93	40.0	0.443	17.99	187.3	174.0	41.28	66.60
4	17.83	44.7	0.465	15.32	180.0	167.5	40.93	63.78
5	11.21	52.7	0.346	9.09	157.7	142.9	40.62	61.05
6	15.50	40.8	0.369	13.33	174.0	157.9	40.66	66.55
14	4.36	15.6	0.040	29.90	212.	75.03	41.68	119.1
17	2.985	63.5	0.798	0.96	78.0	73.0	43.83	61.7
18	2.983	6.85	0.086	18.33	188.2	183.8	43.20	178.0
19	3.27	13.3	0.184	4.97	133.7	129.9	43.91	123.1
20	1.83	33.4	0.258	1.19	84.5	78.3	44.35	78.15
21	11.46	6.67	0.322	25.13	203.3	189.0	43.45	190.6
34	14.81	44.3	2.67	2.16	104	103.5	47.59	72.6
35	30.84	40.3	5.24	7.88	151.7	140.8	47.51	73.33
62	7.40	64.0	5.00	1.115	82.6	78.65	42.93	61.80
63	23.79	20.7	5.20	7.29	148.7	138.0	42.93	94.70
64	44.75	12.1	5.72	27.27	207.2	190.1	42.93	124.6
39	3.023	19.0	0.670	2.19	104.4	103.2	44.11	101.7
40	3.629	5.90	0.226	24.49	202	193.0	45.09	192.5
41	3.399	39.3	1.41	1.04	80.5	77.15	44.82	73.15
42	10.52	14.7	1.63	6.06	141.3	121.2	44.38	117.8
43	8.737	11.4	1.05	6.93	146.7	143.4	44.51	134.2
47	5.559	81.9	4.80	1.59	93.85	60.18	43.71	57.80
65	5.01	30.1	1.59	1.82	98.2	82.95	44.55	80.30
66	13.05	14.2	1.95	5.45	137.1	133.	44.55	118.0
67	25.81	8.25	2.24	22.77	198.7	186.5	44.55	160.2
68	3.22	9.18	0.146	10.06	161.9	149.2	48.91	153.2
70	22.18	18.1	2.07	21.53	196.0	178.0	48.44	107.1
73	27.75	23.6	3.25	21.07	194.9	179.3	45.13	87.4
75	2.65	235.	3.09	1.18	84.45	65.4	45.02	50.56
83	3.284	6.99	0.114	30.02	212.3	96.0	41.00	195.2
84	26.43	21.0	2.17	28.52	209.7	201.2	56.40	102.0
85	23.75	19.2	1.78	29.54	211.5	192.3	56.40	108.15
97	11.81	47.7	0.842	4.04	126.1	120.9	62.40	85.15
98	27.31	24.2	0.990	14.45	177.4	168.7	62.00	105.25
99	38.01	20.6	1.17	24.49	202.0	190.6	61.60	111.2
148	5.14	23.2	1 44	1.601	94.1	91.1	40.50	88.00
149	13.63	10.1	1.66	8.39	154 2	150.	40.50	142.2
150	9.71	35.0	4.10	1.412	90.1	82.5	39.56	70.4
151	23.36	14.9	4.22	7 192	148.0	144.3	39.56	109.0

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* Tests made by J. P. Joule and published in Phil. Trans. Royal Soc., 1861, p. 133.

HEAT TRANSFER TESTS*

Temperature Rise Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio of Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg. Fahr. Per Hour	
$t_1 - t_0$	θ	$l \div d$	U	
27.07	36.85	6.35	108.7	Copper steam tube, 4 in. long, 0.75 in. outside diameter, 0.63 in. inside diameter. Total inside surface, 0.66 sq. ft. Water area, 1.0976 sq. in. Outer tube 1.4 in. inside diameter. Flow counter-current.
63.37	55.0	6.35	172	
25.32	133	6.36	219	
22.85	128.2	6.35	216	
20.43	107.1	6.35	171	
25.89	120.2	6.35	206	
77.42	127.2	6.35	62.5	
17.87	24.2	6.35	212	Same steam tube. Outer tube 0.87 in. inside diameter. Water area 0.1523 sq. in. Flow counter-current except Tests 34 and 35, in which steam and water flow in the same direction.
134.8	50.8	6.35	82	
79.19	37.1	6.35	141	
33.80	18.3	6.35	171	
147.15	58.1	6.35	293.5	
25.01	42.8	6.35	349	
25.82	90.6	6.35	538	
18.87	29.4	6.35	460	Same steam tube. Outer tube 0.8 in. inside diameter. Inner tube rubbed with oil. Water area 0.0609 sq. in. Flow counter-current.
51.77	77.0	6.35	503	
81.67	118.6	6.35	566	
57.59	18.5	6.35	271	Same steam tube. Outer tube 0.8 in. inside diameter. Water area 0.0609 sq. in. Counter-current.
147.41	52.5	6.35	91	
28.33	17.9	6.35	320	
73.42	51.9	6.35	332	
89.69	42.6	6.35	317	
14.09	42.9	6.35	226	
35.75	32.6	6.35	250	Same tubes. Oil cleaned off after Tests 62–64. Water and steam in same direction.
73.45	46.5	6.35	442	
115.65	81.8	6.35	456	
104.29	40.7	7.69	139	Lead tube 4 ft. long, 0.77 in. outside diameter, 0.52 in. inside diameter. Outer tube 0.87 in. inside diameter. Inside surface 0.545 sq. ft. Water area 0.1288 sq. in. Counter-current flow.
58.66	115.7	7.69	389	
42.27	127.8	7.69	398	
5.54	36.7	7.69	173	
154.2	67.0	7.69	97	
45.6	128.7	6.65	313	Iron tube 4 ft. long, 0.74 in. outside diameter, 0.602 in. inside diameter. Outer tube 0.87 in. inside diameter. Surface 0.63 sq. ft. Water area 0.164 sq. in. Counter current.
51.75	127.5	6.65	294	
22.75	51.5	6.35	377	Copper tube again. Outer tube 1.4 in. inside diameter. Spiral 0.1 in. diameter copper wire 30 turns around inner tube—half l.h. Water area 0.429 sq. in. Counter-current.
43.25	92.1	6.35	470	
49.6	113.5	6.35	518	
47.5	20.8	6.65	431	Iron tube as above. Outer tube 0.87 in. inside diameter. Spiral of 55 turns 0.055 in. copper wire wound on inner tube. Water area 0.053 sq. in. Tests 148, 149 steam and water in same direction. Tests 150, 151 counter-current.
101.7	45.2	6.65	492	
30 84	32.8	6.65	507	
69 44	67.9	6.65	566	

TABLE 11 CONDENSER TESTS*

SURFACE = 25000 SQ. FT. TWO PASS. WATER AREA. 13.22 SQ. FT. 5960 TUBES, 16 FT. LONG, 1 IN. OUTSIDE DIAMETER, 18 B.W.G.

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam $\frac{Q}{W}$	Absolute Pressure of Steam, In. of Mercury	Velocity of Water, Ft. Per Sec.	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature of Rise Water, Deg. Fahr.	$\text{Log}_e \frac{t_s - t_o}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Fahr., Difference Per Hour
No.	W	R	p	V_w	t_s	t_p	t_o	t_1	$t_1 - t_0$	log	θ	U
38	237480	53.5	1.51	42.7	92	71.2	37.7	57.3	19.6	0.445	43.8	227
39	187193	48.2	1.59	3.04	94	76.2	39.9	62.5	22.6	0.542	41.7	195
40	170661	52.9	1.22	3.04	85	71.0	32.0	51.8	19.8	0.470	42.1	168
41	160229	46.4	1.30	2.50	87	73.4	34.0	56.8	22.8	0.565	40.3	168
42	147142	42.7	1.32	2.11	88	75.2	31.8	56.7	24.9	0.588	42.4	147
43	138766	44.2	1.47	2.06	91	80.2	32.8	57.1	24.3	0.542	44.8	132
44	122689	107.7	0.94	4.44	77	59.4	31.6	42.0	10.4	0.262	39.6	139
48	114372	118	1.20	4.54	85	60.6	32.9	42.1	9.2	0.1906	48.3	103
51	133462	150	1.18	6.72	84	65.2	37.5	43.1	5.6	0.1310	42.7	104
54	176565	77.1	0.94	4.57	77	57.3	33.5	47.8	14.3	0.3988	35.6	218
55	99210	112	1.16	3.73	84	58.6	33.1	41.3	8.2	0.1740	47.1	77
56	158112	63.4	1.02	3.37	80	60.7	33.4	50.1	16.7	0.4447	37.5	178
57	182508	77.5	0.86	4.75	74	53.2	33.3	47.6	14.3	0.432	33.1	244
58	81533	153	0.98	4.20	78	53.9	33.2	39.5	6.3	0.151	41.7	75
59	120863	108	0.94	4.67	77	59.1	33.4	43.7	10.3	0.270	38.2	141
60	141930	82.9	0.88	3.94	75	59.6	33.3	46.0	12.7	0.365	34.8	172
61	143958	108	1.00	5.22	79	61.7	33.1	47.2	14.1	0.365	38.6	227
62	206603	49.0	1.18	3.41	84	62.8	33.6	56.0	22.4	0.588	38.1	239
5	150170	89.0	1.89	4.50	100	88.1	72.1	84.0	11.9	0.554	21.5	296
6	167190	8.05	1.58	4.52	94	87.6	74.7	87.7	13.1	1.135	11 7	605
7	164945	78 3	1.37	4.35	89	85.5	72.5	85.0	13.5	1.703	7.91	889
8	161612	86.5	1.48	4.70	92	86.9	74.4	86.6	12.3	1.182	10.3	659
9	164458	79.0	1.74	4.36	97	87.8	72.8	86.3	13.5	0.815	16.6	426
10	185100	93.5	2.01	5.82	102	89.5	72.0	83.3	11.3	0.470	24.0	325
11	136850	94.5	2.00	4.35	102	87.3	72.4	83.5	11.1	0.470	23.6	243
12	192290	76.5	1.93	4.94	100	90.7	75.4	89.2	13.8	0.820	16.8	484
13	156470	96.0	1.94	5.06	100	88.2	72.8	83.8	11.0	0.519	21.2	311
14	176210	78.6	1.63	4.65	94	86.4	73.0	86.6	13.6	1.044	13.1	576
15	167103	69.0	2.41	3.88	107	91.8	78.2	93.5	15.3	0.751	20.4	347
16	167088	82.0	2.50	4.61	109	92.9	78.6	91.5	12.9	0.554	23.2	303
17	179170	81.0	2.30	4.86	106	86.4	73.6	86.7	13.1	0.519	25.3	300
18	149148	98.0.	2.27	4.92	106	89.7	72.8	83.6	10.8	0.382	27.5	229
19	201351	66.0	2.14	4.46	104	90.9	72.2	88.2	16.0	0.698	22.9	371
20	196680	51.0	2.17	3.37	104	90.3	72.6	93.7	21.1	1.105	19.1	444
21	144399	85.0	1.89	4.13	99	87.8	72.5	84.4	11.9	0.593	20.1	291
23	195514	75.5	2.20	4.95	105	91.1	73.0	87.0	14.0	0.571	24.5	337
24	173150	78.5	2.13	4.56	103	89.8	73.3	86.8	13.5	0.599	22.5	326
25	134635	101	2.14	4.56	104	88.8	72 3	82 8	10.5	0.399	26.3	207
26	161983	91.0	2.44	4.93	108	88.2	73.1	84.9	11.8	0.412	28.6	246

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* Tests run on 59th Street Exhaust Turbine Base Condenser by H. G. Stott and R. J. S. Pigott and published in The Journal of the Society, March 1910.

TABLE 12 HEAT TRANSMISSION*

Series Number	Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Water Velocity, Ft. Per Sec.	Absolute Pressure, In. of Mercury	Steam Temperature, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Outlet Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\log_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Difference Per Hour.
No.	No.	W	R	V_w	p	t_s	t_p	t_0	t_1	$t_1 - t_0$		θ	U
Series† *A*	987	1739	31.8	4.45	1.36	88.9	90.0	45.3	75.3	30.0	1.1663	25.7	646
	988	1992	28.2	4.52	1.63	94.7	92.4	45.2	79.0	33.8	1.1474	29.5	645
	989	1844	24.6	3.66	2.03	101.9	97.1	45.3	85.0	39.7	1.2090	32.8	549
	990	1986	17.7	2.85	2.46	108.4	112.0	45.5	101.0	55.5	2.1401	25.9	753
	991	1899	13.3	2.06	3.97	125.4	128.9	45.7	118.7	73.0	2.4759	29.5	623
	992	1781	8.5	1.24	11.94	169.2	171.6	46.0	161.7	115.7	2.7972	41.4	422
Series *B*	998	1121	49.2	6.38	0.80	72.6	72.2	46.0	66.7	20.7	1.504	13.15	829
	999	1101	41.1	5.20	0 80	72.6	75.1	46.0	70.5	24.5	2.53	9.68	1145
	1000	1073	34.5	4.23	0.90	76.2	79.5	46.2	75.8	29.6	4.32	6.86	1600
	1005	1517	24.2	4.21	1.41	90.1	95.4	46.5	89.8	43.3	4.98	8.69	1830
	1007	1400	11.6	1.82	5.36	136.6	138.6	47.5	135.6	88.5	4.48	19.6	729
	1008	1781	30.9	6.37	1.16	83.9	88.2	46.5	81.3	34.8	2.667	13.0	1465
	1009	1716	26.7	5.28	1.21	85.2	90.09	46.8	84.6	37.8	4.15	9.11	1905
	1010	1987	18.4	4.21	2.13	103.3	106.1	46.2	101.3	55.1	3.51	15.7	1283
	1011	1840	14.3	3.00	3.33	119.0	121.9	46.4	118.2	71.3	4.50	15.8	1184
Series *C*	1014	1265	45.9	4.56	1.03	80.2	76.3	46.0	68.0	22.0	1.0367	21.2	602
	1015	1302	35.9	3.66	1.03	80.2	79.9	46.0	72.5	26.5	1.4907	17.7	695
	1016	1194	30.7	2.85	1.18	84.4	86.2	46.1	78.7	32.6	1.9051	17.1	698
	1017	1191	22.3	2.04	1.55	93.1	95.3	46.3	88.3	42.0	2.2762	18.5	603
	1018	1170	13.8	1.22	3.93	125.0	123.5	46.9	119.7	72.8	2.686	27.1	433
	1031	1180	22.4	2.03	1.47	91.4	90.2	42.6	84.5	41.9	1.943	21.5	512
	1032	1148	51.5	4.65	0.95	77.8	76.5	42.0	60.8	18.8	0.7324	25.8	433
	1033	1681	35.3	4.66	0.98	78.7	77.5	42.0	68.5	26.5	1.2809	20.7	759
	1034	1570	16.8	2.04	2.56	110.0	109.7	42.5	102.0	59.5	2.1318	27.9	561
	1035	1848	14.2	2.03	3.48	120.5	121.9	42.5	114.0	71.5	2.4849	28.8	653
Series *D*	1055	2208	26.0	4.63	1.95	100.4	101.3	41.3	77.2	35.9	0.9322	38.5	865
	1056	2214	20.5	3.67	2.70	111.6	114.0	41.4	88.3	46.9	1.1019	42.7	806
	1057	2288	15.3	2.83	4.43	129.4	132.0	41.5	104.3	62.8	1.2528	50.1	705
	1058	1788	31.3	4.51	1.68	95.7	104.0	41.2	72.0	30.8	0.8329	37.1	753
	1059	1753	25.7	3.53	1.92	100.0	106.0	41.4	79.3	37.9	1.0403	36.4	757
	1060	1776	19.9	2.85	2.65	111.1	115.3	41.5	89.7	48.2	1.1787	40.9	672
	1061	1722	14.4	2.01	4.40	129.0	132.0	41.7	108.0	66.3	1.4255	46.6	570
Series *E*	1092	1157	47.6	6.48	0.98	76.8	75.0	43.5	61.8	18.3	0.7975	23.0	708
	1093	1105	32.1	4.17	1.13	83.1	81.7	44.1	72.5	28.4	1.3029	21.8	745
	1100	1649	33.6	6.47	0.90	76.1	78.7	40.0	62.6	22.6	0.9821	24.1	876
	1099	1646	22.1	4.17	1.40	90.0	94.0	40.0	82.0	42.0	2.1199	19.8	1242
	1098	1559	13.9	2.40	2.90	114.0	120.0	40.0	107.6	67.6	2.459	27.5	859
	1095	2191	25.7	6.52	1.43	90.5	88.0	40.0	76.2	36.2	1.2613	28.7	1145
	1096	2099	17.2	4.17	2.30	106.0	107.7	40.0	95.3	55.3	1.8197	30.4	1060
	1097	2010	10.4	2.39	5.70	139.0	142.0	40.3	129.7	85.4	2.3656	36.1	797

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* Test made by R. L. Weighton and published in the Proceedings of the I. N. A., April 5, 1906.

† Series *A*—100 Sq. ft. surface—Ordinary air pump. Tubes $\frac{5}{8}$ in. outside diameter, 16 ft. total length
Series *B*—100 sq. ft. surface—Dry air pump-cores.
Series *C*—100 sq. ft. surface—Dry air pump.
Series *E*— 62 sq. ft. surface—Ordinary air pump. Tubes $\frac{5}{8}$ in. outside diameter, 10 ft. total length.
Series *F*— 62 sq. ft. surface—Dry air pump-cores.

TABLE 13 CONDENSER TESTS*

Test Number	Steam Condensed Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Average Velocity of Water, Ft. Per Sec.	Absolute Pressure in Condenser, In. of Mercury	Temperature of Steam, Deg. Fahr.	Hot Well Temperature, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature End First Pass, Deg. Fahr.	Temperature End Second Pass, Deg. Fahr.	Temperature End Third Pass, Deg. Fahr.
No.	W	R	V_w	p	t_s	t_p	t_0	t_a	t_b	t_c
1	4000	51.4	See Table 13*a*	1.15	82.25	58.45	50.39	51.7	61.6	65.9
2	3985	34.6		1.39	90.0	68.9	50.42	52.6	69.9	75.35
3	4023	24.0		2.05	102.0	79.5	50.37	61.1	80.7	87.8
4	4050	18.73		2.79	113.0	89.6	50.4	65.4	90.5	99.0
5	2453	86.7		0.98	79.9	52.7	50.4	50.62	54.7	57.5
6	2427	49.8		1.06	81 9	54.0	50.4	50.93	60.4	65.8
7	2421	37.8		1.16	84.6	56.65	50.42	53.05	67.55	72.85
8	2421	30.15		1.42	90.0	65.65	50.42	56.57	73.9	79.35
9	2417	22.87		1.95	101.0	75.55	50.43	60.9	83.8	90.15
10	2457	16.7		3.05	115.5	93.0	50.45	67.6	99.15	106.5
101	12800	98		1.10	80.6	68.9	49.1			
102	7740	169		0.90	75.2	58.1	49.1			
103	1876	596		0.70	68.0	47.3	45.5			
111	154,400	21.1	7.52	5.27	133		59.2	73.4		
6–1	7665	32.6		1.55	93.2	65.85	50.76			
6–2	4837	43.1		0.93	80.6	57.2	50.76			
6–3	6250	38.4		1.11	84.25	62.42	50.76			
6–5	7685	32.1		1.98	102.05	79.17	50.76			
6–6	5890	40.4		1.49	93.55	71.08	50.76			
6–7	4750	44.1		1.30	90.95	68.6	50.76			
6–8	6070	41.9		1.40	92.15	70.0	50.76			
4–1	6870	39.2	1.275	1.15	82.3	64.4	50.55	61.1		
4–2	7018	28.5	0.945	1.52	92.3	69.1	50.55	68.6		
4–3	6890	22.1	0.719	2.04	102.3	77.7	50.71	79.5		
4–4	7133	17.4	0.588	2.87	114.1	87.5	50.55	93.8		
411	7133	36.9	1.246	2.16	104.2	87.3	71.9	88.3		
410	5760	46.0	1.256	1.67	95.6	80.8	70.2	82.5		
412	3898	67.3	1.241	1.32	88.9	77.7	71.6	79.0		
4–8	6865	24.9	0.810	1.79	97.9	71.4	50.55	75.6		
4–9	4542	38.0	0.816	1.12	81.9	62.8	50.55	63.35		
413	3221	54.5	0.829	0.80	72.7	58.1	50.36	55.5		
414	3182	82.3	1.239	0.65	66.6	54.5	50.36	51.1		
4–5	7200	19.6	0.668	2.48	108	82.7	50.55	85.15		
4–6	7050	19.9	0.663	2.93	114.1	69.7	50.55	62.41		
4–7	6975	20.2	0.668	3.40	119.8	61.2	50.55	54.05		

* Tests made by E. Josse and published in Zeitschrift des Vereines deutscher Ingenieure, February–March 1909.

† $\frac{l}{d}$ and U figured on inside diameter of tubes in all tests

‡ Test 111 was on a turbine condenser with 6085 sq. ft. of surface, Number and size of tubes not given

TABLE 13 CONDENSER TESTS—Con.

Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	Mean Temperature Difference, Deg. Fahr.	Ratio Length in Ft. to Diameter in In.	B.t.u. Per Sq. Ft. Per Deg., Difference Per Hour	$\log_e \frac{t_s - t_0}{t_s - t_1}$	
t_1	$t_1 - t_0$	θ	$l \div d$	U		
71.23	20.84	19.60	23.6†	710	1.0613	Double condenser of 307 sq. ft. surface. Tubes 0.59 in. inside diameter in upper and 0.51 in. inside diameter in lower shell. 620 tubes. Length of water passage 13.93 ft.
81.15	30.73	20.50	23.6	673	1.4974	
94.1	43.73	23.3	23.6	590	1.8779	
105.7	55.3	25.7	23.6	531	2.1494	
62.37	11.97	23.1	23.6	359	0.5188	
71.2	20.8	19.3	23.6	425	1.0791	
77.9	27.48	16.9	23.6	485	1.6292	
84.4	33.98	17.38	23.6	464	1.9559	
95.8	45.37	19.95	23.6	408	2.2742	
111.7	61.25	15.95	23.6	512	3.8396	
59.9	10.8	25.8		280	0.4187	Surface 1883 sq. ft., size of tubes not reported.
55.4	6.3	22.75		194	0.277	
47.3	1.8	21.5		492	0.0839	
‡103.5	44.3	48.3		490	0.9163	
83.70	32.94	22.0		388	1.497	Condenser of 959 sq. ft. surface. In Tests 1–3 the tube contained spirals. Tests 5–8 had plain tubes.
75.4	24.66	14.1		378	1.748	
78.4	27.66	15.85		435	1.746	
82.6	31.86	32.8		250	0.9708	
76.85	25.99	27.65		234	0.940	
75.15	24.39	26.15		203	0.9322	
75.7	24.94	27.0		243	0.9243	
77.8	27.25	13.95	21.3	553	1.953	Double condenser. Total surface 962 sq. ft. 688 tubes 708 in. inside diameter, 787 in. outside diameter, half in. in each section. Area water pass 0.94 sq. ft. Total length water pass 15.08 ft.
88.3	37.75	16.1	21.3	488	2.344	
98.8	48.09	17.89	21.3	431	2.689	
110.1	59.55	21.5	21.3	395	2.766	
100.9	29.0	12.7	21.3	630	2.281	
93.1	22.2	9.59	21.3	640	2.318	
87.4	15.8	6.46	21.3	668	2.444	
93.9	43.35	17.53	21.3	443	2.470	
79.15	28.6	11.75	21.3	441	2.434	
69.95	19.59	9.36	21.3	379	2.094	
63.35	12.99	8.07	21.3	441	1.609	
104.6	54.05	19.11	21.3	418	2.827	
104.9	54.35	28.1	21.3	283	1.933	
104.9	54.35	35.4	21.3	227	1.535	

TABLE 13*a* TESTS 1 TO 10

WATER VELOCITIES, FT. PER SEC.

Test No.		1	2	3	4	5	6	7	8	9	10
Upper Condenser	Upper Tubes..........	5.52	3.705	2.60	2.035	5.72	3.25	2.46	1.96	1.484	1.10
	Center (Cross) Tubes.	2.54	1.71	1.194	0.94	2.63	1.50	1.135	0.907	0.684	0.51
	Lower Tubes.........	3.61	2.424	1.70	1.33	3.74	2.13	1.61	1.29	0.973	0.723
Lower Condenser		3.03	2.04	1.43	1.12	3.15	1.79	1.35	1.08	0.815	0.605

TABLE 14 HEAT TRANSMISSION TESTS *

MADE ON TUBE OF SHELBY COLD DRAWN STEEL, 1.253 IN. OUTSIDE DIAMETER, 0.985 IN. INSIDE DIAMETER, 6 FT. 7¼ IN. LONG INSIDE CONDENSER†, $\frac{l}{d} = 5.27$, $S = 2.14$ SQ. FT.

Series Number	Test Number	Circulating Water Per Hour, Lb.	Ratio of Water to Steam, $\frac{Q}{W}$	Velocity of Water in Tube, Ft. Per Sec.	Absolute Pressure in Condenser, Lb. Per Sq. In.	Temperature of Steam, Deg. Fahr.	Temperature of Inlet Water, Deg. Fahr.	Temperature of Discharge Water, Deg. Fahr.	Temperature Rise of Water, Deg. Fahr.	$\log_e \frac{t_s - t_0}{t_s - t_1}$	Mean Temperature Difference, Deg. Fahr.	B.t.u. Per Sq. Ft. Per Deg. Fahr., Per Difference Per Hour
	No.	Q	R	V_W	p	t_s	t_0	t_1	$t_1 - t_0$		θ	U
Series *A*	1	19100	98.4	16.07	14.38	210.9	56.92	66.75	9.83	0.0658	149.0	587
	2	15800	80.2	13.29	14.38	210.9	58.20	70.25	12.05	0.0824	146.3	608
	3	14150	72.4	11.93	14.38	210.9	58.55	71.90	13.35	0.0915	146.0	605
	4	12250	66.4	10.33	14.38	210.9	58.63	73.20	14.57	0.1027	141.9	588
	5	10560	58.1	8.90	14.38	210.9	58.20	74.82	16.62	0.1142	145.0	565
	6	8820	55.6	7.43	14.38	210.9	57.89	75.28	17.39	0.1221	142.5	503
	7	7200	47.6	6 07	14 38	210.9	58.20	78.52	20.32	0.1424	142.6	480
	8	4860	36.9	4.11	14.38	210.9	58.29	84.49	26.20	0.1890	138.6	430
	9	3310	28.7	2.80	14.38	210.9	58.37	92.00	33.63	0.2493	135 0	385
	10	1740	19.5	1.48	14.38	210.9	58.91	108.4	49.50	0.3934	126.0	319
	11	427	8.38	0.37	14.38	210.9	60.10	175.5	115.4	1.4481	79.8	289
Series *B*	1	19900	62.3	16.78	44.49	273.6	58.55	73.35	14.80	0.0724	204.5	673
	2	14680	46.5	12.37	45.08	274.4	58 32	78.12	19.80	0.0962	206.0	658
	3	17670	53.3	14.89	44.56	273.7	58.15	75.45	17.30	0.0816	212.0	673
	4	12030	40.0	10.15	44.71	273.9	57.90	80.94	23.04	0.1133	203.0	638
	5	9350	33.2	7.89	44.85	274.1	58.03	85.83	27.80	0.1354	205.0	591
	6	6970	25.5	5.88	44.85	274.1	58.10	92.88	34.78	0.1757	198.0	572
	7	3458	16.0	2.94	44.85	274.1	62.87	120.46	57.59	0.3185	181.0	514
	8	4580	20.4	3.89	45.15	274.5	63.28	108.5	45.22	0.2398	188.5	514
	9	2141	11.2	1.84	45.15	274.5	63.73	145.9	82.17	0.4947	166.0	494
	10	1680	9.74	1.45	45.08	274.4	67.55	162.2	94.65	0.6114	155.0	480
Series *C*	1	20870	51.5	17.64	74.15	306.6	67.54	85.00	17.46	0.0770	227.0	750
	2	18400	45.7	15.50	74.15	306.6	67.54	87.19	19.65	0.0862	228.0	741
	3	13570	34.9	11.43	74.05	306.5	67.54	93.30	25.76	0.1142	225.0	725
	4	6280	18.3	5.33	74.37	306.8	58.73	107.7	48.96	0.2199	223.0	645
	5	4910	15.2	4.17	74.59	307.0	58.89	118.05	59.16	0.2715	218.0	622
	6	3720	12.7	3.17	74.59	307 0	59.27	129.7	70.43	0.3345	210.0	582
	7	2550	9.47	2.19	75.03	307.4	59.52	154.35	94.83	0.4806	197.0	574
Series *D*	1	20320	38.6	17.13	103.7	330.2	57.67	80.50	22.83	0.0872	262.0	830
	2	16630	33.7	14.05	103.4	330.0	57.67	83.88	26.21	0.1018	258.0	790
	3	12300	27.0	10.39	103.4	330.0	58.28	90.92	32.64	0.1284	254.0	740
	4	9530	22.2	8.06	103.7	330.2	58.17	97.90	39.73	0.1579	252.0	702
	5	5000	14.2	4.25	103.7	330.2	58.50	120.6	62.10	0.2586	240.0	604
	6	2680	8.60	2.31	103.7	330.2	58.89	161.5	102.61	0.4762	215.0	597

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* Tests made by J. K. Clement and C. M. Garland and published in Bulletin 40 of the University of Illinois, September 27, 1909.

†The condenser was a specially designed apparatus for experimental work at the Engineering Experiment Station of the University of Illinois.

APPENDIX NO. 2

REVIEW OF RESULTS OBTAINED BY DIFFERENT EXPERIMENTERS

CONDENSER TUBE EXPERIMENTS BY J. P. JOULE

Philosophical Transactions, Royal Society, 1861

43 The apparatus used in these tests consisted of a steam boiler, with a 1-in. pipe leading to a vertical condenser tube enclosed by a water pipe of slightly greater diameter. The steam was condensed in passing downward through the condenser tube, and the water of condensation ran out the bottom, where it was collected and weighed in a suitable tank. The cooling water was brought into the water jacket at either top or bottom and taken from the other end to another tank to be weighed. Thus, either counter-flow or parallel-flow was obtained, the cooling water passing through the annular space around the condenser tube while the steam passed on the inside of the tube. Suitable thermometers and mercury columns were provided to determine the temperature and pressure of the steam, the head on the circulating water, temperature rise of the water and the mean temperature difference.

44 The tubes used were of various sizes, thicknesses and material and the water pipe also varied in size. For some tests helical channels were provided for the water by winding wire on the inner tube, giving the circulating water a whirling motion. The length of the tests varied from twenty minutes to an hour.

CONCLUSIONS

45 The following is a summary of his principal conclusions:

a The pressure in the vacuous space is sensibly equal in all parts.

b In the arrangement in which the steam is introduced into a tube whilst the refrigerating water is transmitted along a concentric space between the steam tube and a larger tube in which it is placed, it is a matter of indifference in which direction the water is transmitted, hence,

c The temperature of the vacuous space is sensibly equal in all parts.

d The resistance to conduction is to be attributed almost entirely to the film of water in immediate contact with the outside and inside surfaces of the tube and is little influenced by the kind of metal of which the tube is composed, or by its thickness in the limits of ordinary tubes, or even by the state of its surface as to greasiness or oxidation.

e The narrowing of the steam space by placing a rod in the axis of the steam tube does not produce any sensible effect.

f The conductivity increases as the rapidity of the stream of water is augmented. In the circumstances of my experiments, the conduction was nearly proportional to the cube root of the velocity of the water; but at very low velocities it evidently increases more rapidly than according to this law, whilst at very high velocities it increases less and less rapidly as it gradually approaches a limit determined by the resistance of the metal and of the film of water adhering to the inside surface of the tube.

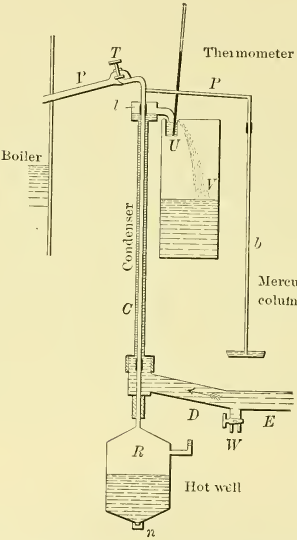


FIG. 12 JOULE'S APPARATUS

g The conductivity increases so slowly in relation to the height of the head of water, that the limit to the economical increase of the latter is soon attained.

h By means of a contrivance for the automatical agitation of the particles of the refrigerating stream, such as the spirals I have employed, an improvement in the conductivity for a given head of water is obtained.

i The total heat of steam above 0 deg. cent. determined by the average of 151 experiments, is 644.28 heat units for a pressure of 47.042 in.

EXPERIMENTS ON SURFACE CONDENSATION

Abstract of a Paper by James Alexander Smith, Read Before the Victorian Institute of Engineers, December 6, 1905

Engineering, March 23, 1906

46 This paper is a sequel to a former paper on Air in Relation to Boiler Feed, Engineering, October 7, 1904.

47 The preliminary experiments were made with closed glass tubes containing bromine both with and without air in the vapor space. The low boiling point, deep non-actinic color of the vapor and strong russet red of the condensed films made the processes of diffusion and condensation easy to follow. The final apparatus consisted of a boiler 3 ft. long, $7\frac{1}{2}$ in. in diameter, made of No. 19 B.W.G. galvanized sheet steel with joints folded, soldered and tarred. The leakage was only sufficient to reduce the mercury gage level $\frac{1}{50}$ of an inch in 24 hours. The boiler was heated externally by 60 gas jets each $\frac{1}{8}$ of an inch in diameter.

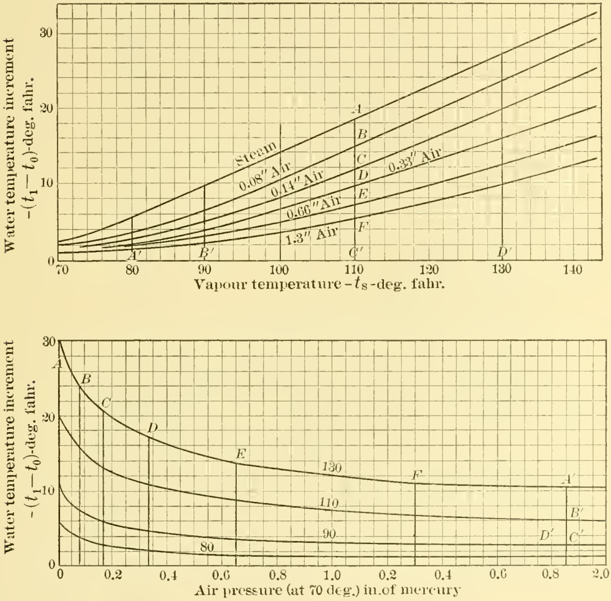


Fig. 13 Variation of Heat Transmission with Air

The boiler was provided with glass windows for observation of the interior and the standard mercury columns, thermometers, etc. The condensing tubes were in two lengths about 3 ft. long, making an effective length of about 6 ft. The external surface exposed to the vapor was exactly 1 sq. ft., external diameter of the tubes about $\frac{5}{8}$ in. thickness 0.018 in., sectional area of the inside tube 0.26 sq. in. Tubes were hard drawn brass.

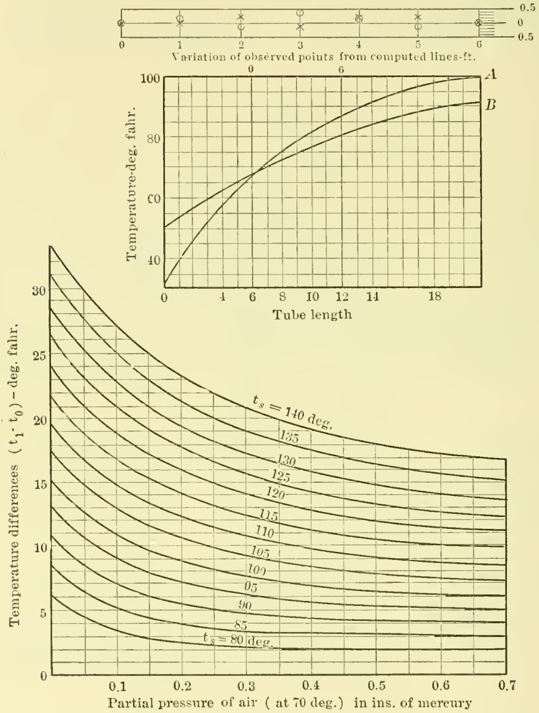


FIG. 14 VARIATION OF HEAT TRANSMISSION WITH AIR

48 Constant-flow apparatus was provided for the condensing water so that various quantities from $2\frac{1}{2}$ lb. to 20 lb. per min. could be passed through the tube. Apparatus was provided whereby, after the boiler was freed from air, a known amount of air at a noted pressure and temperature could be added to the contents of the boiler.

TESTS

49 A series of tests run to determine the effect of air admixture. Air-free steam was condensed at vacuums varying from 70 deg. to 140 deg. at 10 deg. intervals. Air was then added in varying quantities and the process repeated. Another set of tests was made in which the condenser was maintained at constant temperature, while air in the mixture was varied at definite intervals. In both series the cooling water flowed at the constant rate of 10 lb. per min. and the cooling surface was 1 sq. ft. From these experiments it was determined that with constant flow and surface and air-free steam the temperature increment of the cooling water is in a constant ratio to the temperature increment of the steam, at least to a first approximation.

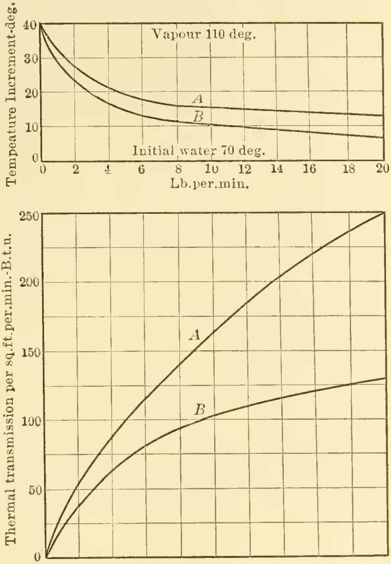


FIG. 15 VARIATION OF HEAT TRANSMISSION WITH WATER VELOCITY

50 The presence of air in the condenser, equal in pressure to $\frac{1}{20}$ of an in. of mercury will at 90 deg. fahr. reduce thermal transmission about 25 per cent, while $\frac{3}{20}$ of an in. of mercury of air pressure will reduce the thermal transmission by one-half.

Corollary 1 The rise in water temperature is proportional to the initial steam and water differences of temperatures.

Corollary 2 Each decrement of condenser temperature requires a proportional increment of cooling surface, provided the tube length is constant.

51 Experiments were made to determine the law of the rise of temperature of the cooling water in the tube, and points were taken 1 ft. apart in the 6 ft. of length of tube, making seven points in all. The temperatures observed at these points under various conditions were plotted and found to lie along an exponential curve, the observed points varying no more than 0.4 of one degree from the calculated curve. When air was admitted to the steam the curve was considerably flatter than with air-free steam. From this it is deduced that economy requires the use of relatively short tubes.

52 Experiments were also made to determine the variation of the heat transmission with the rate of flow of the cooling water. These experiments did not go beyond a water velocity of $2\frac{1}{3}$ ft. per sec., but the tubes were small and in all cases the water was probably above the critical velocity. With air-free steam the transmission at 5, 10 and 15 lb. per min. was in the ratio of 1 to 1.64 to 2.10, while with 2.22 in. of air pressure by mercury gage with the same flows the ratios were 1 to 1.31 to 1.52.

AIR PUMPS

53 It is stated that if air is present only to the extent of $\frac{1}{20}$ of an inch of mercury the ratio of the effective volume of the air pump to boiler feed is 20 to 1. The air pump must be separate from the water removing pump. Air pump inlets should be multiplied in number and so situated that the concentrating air in the vapor will pursue the course of shortest contact with the cooling surface; no dead spaces should be possible.

54 The author's conclusions are:

- *a* If high vapor vacua are required air must be excluded.
- *b* With high vacua climatic conditions are limiting factors and must be specially considered.
- *c* In the absence of exact knowledge the impossibility has been attempted in design. Only by rational condenser proportion will it be possible to push the efficient expansion of steam to those limits that recent improvements in motors seem to render easy of attainment.

TESTS BY GUSTAV A. HAGEMANN

Proceedings of Institution of Civil Engineers, Vol. 77, p. 311, 1883

55 The author refers (page 311) to experiments of Messrs. Easton and Amos of London as the only ones published. These were made on a perpendicular iron tube $\frac{1}{16}$ in. thick and $1\frac{1}{2}$ in. diameter, which was enclosed in a larger tube 3 in. diameter, containing water. Dry steam of known temperature was led into the inner pipe and the amount of steam condensed and the rise of temperature of water was measured. By means of this apparatus a temperature difference of 69.5 deg. cent. gave a heat transmission of 15.3 units of heat per unit of area.

56 The author used an improved apparatus as follows: A brass tube 0.0788 in. thick and 1.93 in. outside diameter and 37 in. long, giving a heating surface of 1.56 sq. ft., was fitted steam tight in the center of a strong cast-iron pipe, about 6 in. inside diameter, the lower end of the brass tube being connected by

a pipe with a tank which contained a copper steam coil whereby the water in the tank could be raised to any desired temperature. The other end of the tube connected to a vessel on a scale. The iron pipe was provided with steam through a smaller pipe tapped into it.

$$t_s - \frac{(t_1 + t_2)}{2} = \text{temperature difference, deg. cent.}$$

t_s being steam temperature and t_1 and t_0 water temperature. If A is weight of water passing in B minutes, $\frac{A}{B}(t_0 - t_1)$ = units of heat transmitted per min. in lb., deg. cent.

$$\frac{2\,A\ (t_0 - t_1)}{B\,S\ [2\,t_s - (t_0 - t_1)\ ]} = \text{units of heat transmitted per sq. ft.}$$

per deg. cent. per min., where S = internal heating surface.

57 After a few tests the space between the inner and outer tubes was found to be too great giving large variations in the temperature readings; accordingly, a tube 1.515 in. in outside diameter, and closed at both ends was placed in the heating tubes, thus reducing the space for the water to pass to an annular area 0.1305 in. in width.

APPENDIX NO. 3

REFERENCES TO TRANSMISSION OF HEAT THROUGH TUBES PARTICULARLY AS APPLIED TO SURFACE CONDENSATION

1835 Poisson. Theorie Mathematique de la Chaleur.

1846 Bourne. A Treatise on the Steam Engine.

1844 Peclet. Experiments on the Conductivity of Metals. Traite de la Chaleur. *Liege.*

1856 Grashof. Angewandte Mechanik. *Leipzig.*

1860 Wye Williams. Heat and its Relation to Steam and Water. *London.*

1861 Joule. Experiments on Transmission of Heat: (1) Steam to Air. (2) Steam to Water. Phil. Trans. Royal Soc., Vol. 151, p. 133.

1871 Burgh. Practical Treatise on the Condensation of Steam.

1873 Rankine. The Steam Engine.

1875 B. G. Nichols. Effect of Velocity of Water in Surface Steam Condensing. Engineering, Vol. 20, p. 449.

1880 Sir William Thomson, Lord Kelvin. Article on Heat. Encycl. Brit., 9th edit., p. 577.

1883 Hagemann. Experiments on the Condensation of Steam and the Influence of Velocity of Cooling Water. Proc. Inst. C. E. Vol. 77, p. 311.

1883 Werner. Increase of Heat Transmission due to the Velocity and Dampness of Gases. Zeitschrift des Vereines deutscher Ingenieure Vol. 26, p. 394.

1887 Ser. Traite de Physique Industrie. *Paris.* Vol. 1 and 2, p. 225.

1887 Reynolds. Effect of the Presence of Air on the Heat Transmission Power of Steam. Zeitschrift des Vereines deutscher Ingenieure, Vol. 31, p. 284.

1888 Lang. Transmission and Evaporation. Trans. Inst. Engrs. and Shipbuilders of Scotland, Vol. 32.

1894 Preston. Theory of Heat.

1895 Foster. Evaporation by the Multiple System, 2d edit., p. 562.

1895 Editorial. Transmission of Heat through Boiler Plates. Engrg. Record, Vol. 32, p. 192.

1896 Boulvin. Mechanique Applique.

1897 Stanton. Passage of Heat through Metal Surfaces in Contact with Liquids. Phil. Trans. Royal Soc., Vol. 190, p. 67.

1897 Callendar and Nicholson. In the Law of Condensation Deduced from the Measurements of Temperature Cycles of the Walls and Steam in the Cylinder of a Steam Engine. Proc. Inst. C. E., Vol. 131, 1897.

1898 Stanton. Surface Condensers. Proc. Inst. C. E., Vol. 136, pt. 2.

1898 Perry. Theory that the Heat Transmitted Varies as the Velocity of the Gases. Trans. Inst. Engrs. and Shipbuilders of Scotland Vol. 42, p. 64.

1899 Richter. 170 Experiments on the Transmission of Heat from Steam to Water. Engrg. Record, Vol. 40, p. 546.

1901 Hepburn. Transmission of Heat from Steam to Water. Power, Vol. 21, p. 18.

1903 Sekutowicz. Engineer, Vol. 96, 1903.

1903 Weiss. Condensation. Hannebique's Translation.

1904 Hausbrand. Evaporation, Condensation and Cooling. Scott, Greenwood and Company, *London.*

1905 Rudolph. Heat Transmission for Condensers. Zeitchsrift für das gesamte Turbinwesen, Vol. 2, p. 262.

1905 Allen. Surface Condenser Plants and the Value of the Vacuum Produced. Proc. Inst. C. E., February 5, 1905.

1906 Weighton. The Efficiency of Surface Condensers. Trans. Inst. Naval Arch., April 1906.

1906 Smith. Experiments on Surface Condensation. Engineering, March 23, 1906.

1907 Tansley. On Heating of Air by Flue Gases. Proc. Inst. C. E., Vol. 171, p. 375.

1908 McBride. Air Leakage in Steam Condensers. Trans. Am. Soc.M.E., Vol. 30, 1908.

1908 Morrison. Steam Condensing Plants for Cargo Steamers. Cassiers, November 6, 1908.

1908 Morrison. The Influence of Air on Vacuum in Surface Condensers. Trans. Inst. Naval Arch., April 1908.

1909 Josse. Test of Surface Condensers in Connection with Steam Turbines. Zeitschrift des Vereines deutscher Ingenieure, February-March 1909.

1909 Clement and Garland. The Transmission of Heat to Water in Tubes as Affected by the Velocity of the Water. Univ. of Ill. Bulletin 40, 1909.

1909 Dalby. Heat Transmission. Engineering (London), October 22, 1909.

1909 Dalby. Discussion on paper Heat Transmission. Engineering (London), October 22, 1909, p. 539.

1909 Wright. The Design of Condensing Plant.

1909 Jordan. Discussion on paper Heat Transmission. Engineering (London), October 22, 1909, p. 541.

1910 Stott and Pigott. Condenser Tests. The Journal Am.Soc.M.E., March 1910.

1910 Editorial. A Study in Heat Transmission, London Engineer, July 8, 1910.

FIRST LARGE GAS-ENGINE INSTALLATION IN AMERICAN STEEL WORKS

By E. P. Coleman

TABLE OF CONTENTS

PAGE

Introduction 1837
General Description of Plant 1838
Furnaces 1839
Piping 1840
Gas Washers 1840
Gas Washers Nos. 1 and 2 1841
Gas Washers Nos. 3 and 4 1844
Blowing-Engine Houses 1851
Oiling System 1858
Power House 1858
Koerting Two-Cycle Engines 1859
General Notes Relating to Operation 1872
Gas-Cleaning and Supply System 1873
Lubrication 1876
Ignition 1877
Governing 1879
Cylinders, Pistons, Rods, Valves, Etc. 1880
Operating Costs 1883
Observed Quantative Results 1885

LIST OF APPENDICES

No. 1 Investigation to Determine Relation between Point of Ignition and Speed of Rotation 1895
No. 2 Diagram Showing Losses Due to Air and Gas Pumps 1900
No. 3 Data upon Efficiency Trials of 2000-h.p. Blowing Engine 1904

FIRST LARGE GAS-ENGINE INSTALLATION IN AMERICAN STEEL WORKS

DESCRIPTION AND OPERATING CHARACTERISTICS OF SIXTEEN BLOWING-ENGINE UNITS OF 2000 H.P. EACH, EIGHT ELECTRIC-GENERATING UNITS OF 1000 H.P. EACH AND GAS-CLEANING PLANTS

By E. P. Coleman, Buffalo, N. Y.

Member of the Society

At the Buffalo works of the Lackawanna Steel Company is located the first gas-engine power plant to be operated in this country with blast-furnace gas. In the following pages it will be attempted to furnish a description of the plant, certain details of its operation and some data of a quantitative nature derived from observation and operation.[1]

2 As far as can be learned, the selection of the type of engine was made in 1900, based on extended observation of the working of blast furnace gas-power plants by a committee in Europe. The types observed were the Cockerill, Otto, Oechelhaueser, and Koerting. The Oechelhaueser engine was disregarded on account of the crank shaft design and the four-stroke cycle engines were not favorably considered on account of exhaust valve troubles which did not seem to have been mastered at that time. The engines were built by the De La Vergne Machine Company, New York, after designs by the firm of Koerting Brothers, Hanover, Germany.

[1] In the collection and tabulation of various of these data, and other matters, the author begs to acknowledge valuable assistance of the following gentlemen: Hugh Boyd, E. E. Kiger, George Conlee, F. C. Baker, F. L. Palmer, F. C. Taylor, R. L. Streeter and Harry Thompson, all of whom are, or have been, members of the engineering department of the Lackawanna Steel Company. The experience of the author at this plant dates from about the early part of 1906.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

3 At this plant 12,000 to 15,000 net h.p. is normally developed by gas engines operated with blast-furnace gas, the greater portion for blowing the furnaces. There are sixteen blowing engines, each rated at 2000 i.h.p., and eight electric power units, each consisting of a gas engine rated at 1000 i.h.p., direct-connected to a 500-kw. generator. Four of these units generate direct current at 250 volts, and the other four generate three-phase 25-cycle alternating current at 440 volts. All of these gas engines are of the two-stroke cycle type, equipped with twin cylinders and cranks spaced 90 deg. apart. A brief general description of the plant used in developing this power will first be given, followed by a more detailed description of the various parts.

GENERAL DESCRIPTION OF PLANT

4 The general arrangement is shown in plan, Fig. 1. There are six blast furnaces in a line extending approximately north and south. These furnaces are grouped in pairs, each pair forming a unit with reference to the arrangement of its stoves, ore bins, gas plant, and other auxiliaries. A seventh furnace not shown is now in operation, but as all of the excess gas from this furnace is burned under boilers, it does not concern the subject under consideration.

5 The blowing engines using gas are located in the two buildings, No. 2 and No. 3 blowing-engine houses. The engines in blowing-engine house No. 2 furnish air for furnaces 3 and 4. Furnaces 5 and 6 are supplied with air by the engines in blowing-engine house No. 3. The air for furnaces 1 and 2 is usually supplied by steam engines located in the north end of blowing-engine house No. 2. Considerable flexibility is secured by means of cross connections, with valves, between the various cold blast mains. The gas-driven electric-generator units are located in the south end of power house No. 1, situated east of blowing-engine house No. 2.

6 The generation of power at this plant requires three principal processes: the production of the gas by the furnaces; the preparation of the gas for use in the gas engines, involving cooling, cleaning and drying; and the development of power by combustion of the gas in the motor cylinders.

7 The general process of preparing the gas for use in the motor cylinders is as follows: the gas leaving the furnace top passes through large downcomer pipes to the dust catcher, where the heavier portion of the dirt is deposited under the action of gravity. From the dust catcher, portions of the gas pass through pipe mains respectively

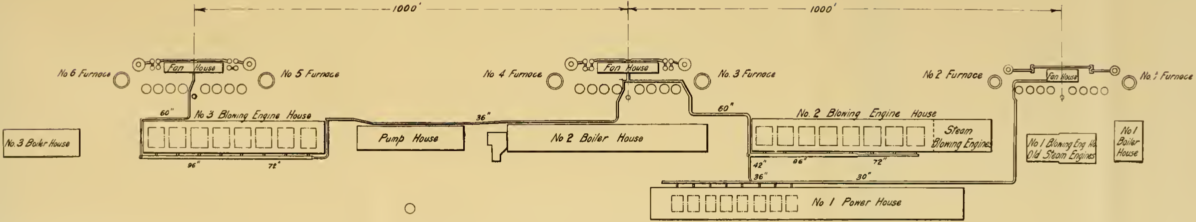


Fig. 1 General Arrangement of Furnaces, Washers, Pipe Lines and Engine Houses

to the hot stoves, the boilers, and the gas engines. That portion used by the gas engines is cooled and partially cleaned by means of water sprays in the pipes and chambers through which the gas passes; after which it is further cleaned by passing through centrifugal fans into which water is also sprayed. From the fans the gas passes through separators which remove the entrained moisture and its entrained dirt, and thence under a few ounces of pressure (above atmosphere) to the engine houses. That portion of gas going to the stoves and boilers receives no further cleaning after leaving the dust catcher.

8 There are eight blowing engines in each blowing-engine house, each rated by the makers at 2000 h.p. In the power house are eight engines rated at 1000 h.p. each

FURNACES

9 The six blast furnaces under consideration produce about 2600 long tons of iron per 24 hr. or about 108 tons per hr. The gas amounts to about 150,000 cu. ft. per ton of iron, or say about 16,000,000 cu. ft. per hr. or more from the six furnaces. Approximately 2,500,000 cu. ft. per hr. is used for the gas-engine plant, the remainder being burned in the hot-blast stoves and under the boilers.

10 Furnaces 1 and 2, located at the northern end, are smaller than the others, being rated at about 300 tons each per 24 hr. The main dimensions are: hearth diameter, 11 ft.; diameter of bosh, 17 ft.; height, 87 ft. There are three downcomers of steel plate construction, each 50 in. in diameter and lined with fire brick to 45 in. diameter. These unite at the top of the dust catcher, which is 20 ft. diameter of shell, and equipped with conical top and bottom. The dust catcher is lined to about 18 ft. 3 in. inside diameter and is about 29 ft. deep from inlet opening to dust valve at bottom. These furnaces operate at about their rating of 300 tons each per day.

11 Furnaces 3, 4, 5 and 6 each make about 500 tons of iron per day. Furnaces 3, 4 and 5 are alike in general dimensions. The hearth is 15 ft. 9 in. diameter; bosh, 22 ft. 9 in. diameter; and the height above hearth is 94 ft. Furnace 6 has corresponding diameters of 15 ft. and 22 ft. and is 94 ft. high.

12 Three downcomers of steel plate, each 6 ft. 6 in. in diameter, lined to 5 ft. 9 in. inside diameter, take the gas to the dust catcher, which is 32 ft. in diameter, lined with 9-in. fire brick, equipped with conical top and bottom, and about 39 ft. deep from top gas inlet to dust valve at bottom of hopper.

13 All of the dust catchers are provided with a suspended partition or baffle wall of firebrick cutting off direct passage of gas from inlet to outlet; the gas having to pass under this wall and up to the outlet. The location of these furnaces is shown in Fig. 1.

PIPING

14 The general arrangement and involved main dimensions of the piping for washed gas are shown in Fig. 1. Each group of eight blowing engines is served with washed gas through a 60-in. overhead main of riveted steel plate delivering gas to a main header of 96 in. diameter situated along the wall of the engine house near the yard level. The eight 1000-h.p. engines at power house No. 1 are supplied with gas from furnaces 1 and 2 through a 30-in. underground pipe of cast iron. This 30-in. pipe is cross-connected with the 96-in. header near the south end of blowing-engine house No. 2, by means of a 42-in. overhead pipe. Gas washers 3 and 4 are connected with gas washers 5 and 6 through a 36-in. equalizing pipe as shown. Low points in the piping are provided with drains. The general arrangement of this piping deserves adverse criticism, as will be shown. No gas holders are installed or required. The length of the 30-in. main supplying the power house is about 1180 ft. The 60-in. main supplying engine house No. 2 is about 525 ft. long, and the 96-in. header at blowing-engine house No. 3 is supplied through about 415 ft. of 60-in. pipe. In this main at the south end of the engine house is a 60-in. venturi meter. The blowing-engine house header lies along the east side of the building. It is supported on the concrete work of the exhaust tunnel and is about 400 ft. long. The 8-ft. section is 255 ft. long and is of riveted $\frac{3}{8}$-in. plate. The plates of the 6-ft. portion are $\frac{5}{16}$ in. thick. A 24-in. connection is taken off for each engine on the side nearest the building. Water is drained from the header by means of an inverted siphon. The total length of piping from the washers to the engine houses is about 3800 ft.

GAS WASHERS

15 There is a gas-cleaning plant at each pair of furnaces consisting of chambers equipped with water sprays for cooling the gas and washing out a portion of the dirt, centrifugal fans also provided with water sprays, separators for removing the entrained water, and the necessary valves and piping. Symbolic diagrams, Figs. 2 and 3,

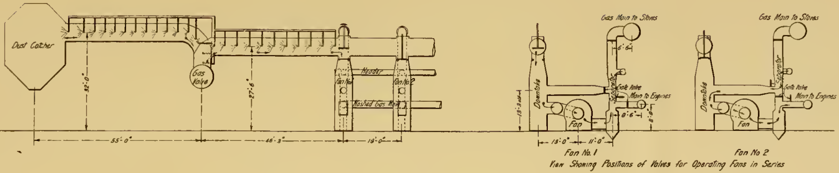


FIG. 2 DIAGRAM OF GAS WASHING PLANT FOR FURNACES 1 AND 2

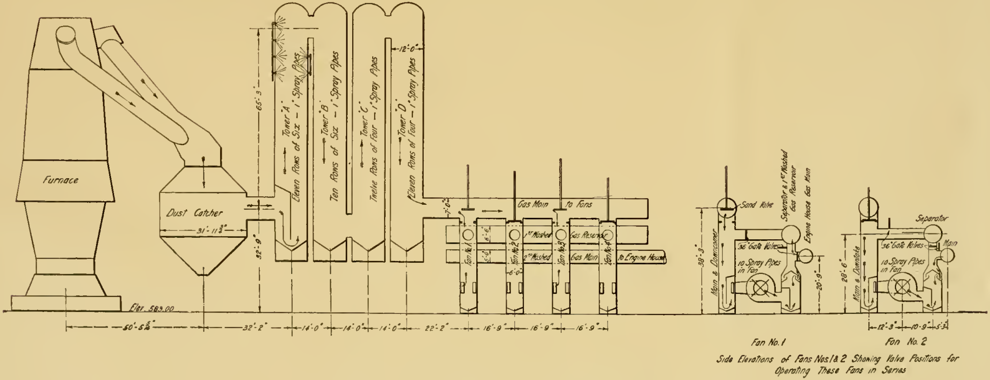


FIG. 3 DIAGRAM OF GAS WASHING PLANT FOR FURNACES 3 AND 4

represent the general scheme. Fig. 2 shows the washery first installed at furnaces 1 and 2. Fig. 3 indicates the arrangement of apparatus at furnaces 3 and 4. The general arrangement of washers at furnaces 5 and 6 is similar to that at furnaces 3 and 4.

GAS WASHERS NOS. 1 AND 2

16 Fig. 2 shows the schematic arrangement of this cleaning plant. Gas is taken from the dust catchers through horizontal pipes where it is given an initial cooling and washing by means of water sprays. The cool gas then passes to four fan washers located between the two furnaces. These fans are normally operated in pairs, each pair forming a unit consisting of the two fans operating in series with each other. The first fan draws cool gas from the main supply and discharges it to a first-washed main. The second fan takes its gas from this main and discharges it to the second-washed main, from which the gas passes to the 30-in. gas line and to the power house.

17 The pipe leading from dust catcher to fans is 70 in. in diameter. At a point about midway between the fans and the dust catcher a water seal valve is located, consisting of a horizontal steel tank 8 ft. in diameter, through which the gas passes on its way to the fans. By filling with water it acts as a shut-off valve and by partly filling with water the gas flow may be reduced to any desired extent, these functions being useful when a furnace is working badly and giving a poor quality of gas. The 8-ft. tank also serves as a receptacle to which the water is drained from the cooling sprays.

18 The 70-in. pipe connecting the dust catchers to the fans is about 236 ft. in length, the total travel of the gas from dust catcher to fan being about 123 ft. Located in this piping are 99 water sprays for cooling the gas on its way to the fan washers. These spray nozzles are located at the axis of the pipe, about 3 ft. 6 in. apart, and discharge a cone-shaped spray into and against the flowing stream of gas. The sprays are supplied from a 3-in. header through 1-in. pipe connections and each spray consumes about 8 gal. of water per min. The water drains first into the 8-ft. tanks and from thence through a seal into tank cars beneath, where the dirt is deposited and the water passes off from an overflow into the general drainage system.

19 The connections to the fans are taken from the bottom of the 70-in. main, the connection being 48 in. in diameter, enlarging to 70 in. diameter. Each connection can be shut off from the gas pipe by means of a disc valve operated by a chain drum and handwheel located

on top of the gas pipe. Each of these connections is provided with a hopper bottom, valve and drain, forming a pocket for the mud and water brought down with the gas. The drain pipe extends downward into a well, forming a seal.

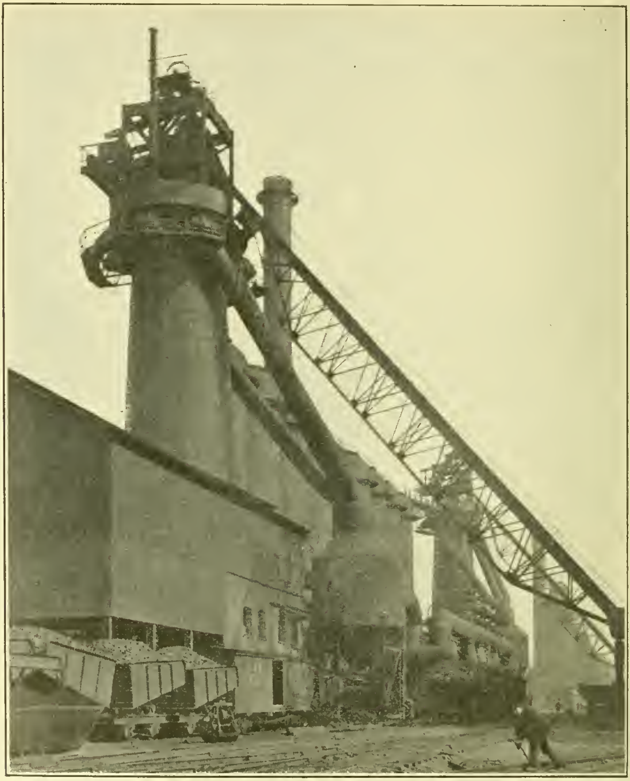


Fig. 4 Piping at Furnaces 1 and 2

20 The four fans are housed in a steel frame building enclosed with corrugated steel sides and roofing and open for light and ventilation on all sides.

21 The fans are very similar in general features to ordinary centrifugal ventilating fans. The wheels are 6 ft. 11 in. in diameter. There are 8 blades, each $15\frac{1}{2}$ in. wide at the inner end and 13 in. wide at the tip, carried on tee-iron arms set in a cast-iron hub. The wheel is split, and the casing of steel plate is arranged for convenient access to and removal of the wheel.

22 The cast-iron suction connections are rectangular. The main is $20\frac{1}{4}$ in. by 52 in. A branch 21 in. by 48 in. leads to each side of the fan, the opening to the fan casing being 36 in. in diameter. These connections are provided with cleaning holes to facilitate removal of mud. Water connections are provided for four nozzles on each side carried through the casing and discharging through the circular inlet to the fan. Waste water from the furnace tuyeres and bosh plates flows from the furnace troughs into a stand pipe equipped with an overflow located at the proper level, and a portion of the water in the stand pipe passes through pipes to the fans.

23 Each fan is driven by a 75-h.p. electric motor direct-connected to the fan by means of a flexible coupling. Three of these motors utilize alternating current and the remaining motor is of the direct-current type. These motors operate at about 500 r.p.m., the input being normally about 55 h.p. each. Control is by means of a switchboard located in a small brick building just outside the fan house.

24 Each fan discharges horizontally at the bottom through a $21\frac{1}{2}$-in. by 45-in. connection into a water separator. The separator is a box of steel plate 4 ft. square by 9 ft. high, containing a set of baffles consisting of 3 rows of 3-in. steel channels, the flanges of the channel bars facing the stream. The openings between channels are about 1 in. wide, and the spacing is alternate or staggered, such that the streams of gas are broken and turned. The separated water and mud drops to the bottom of the separator and passes out through a seal. The gas leaves the separator at the top through a 24-in. pipe connection.

25 First-washed gas which has passed through one fan passes back into one of the 70-in. vertical connections on the cool gas main, and is isolated from it by means of the disc valve at the top, previously mentioned. The gas then flows through the second-wash fan to the second-washed gas main; and thence through the 30-in. line to the power house.

26 The piping and valves are so arranged that any fan may be used for either first or second washing. The valves in the fan connec-

tions are 24-in. Chapman gates, with seats and discs of cast iron. The water valve and pipe main containing the cooling sprays are shown in Fig. 4.

GAS WASHERS NOS. 3 AND 4

27 The gas passes from the dry-dust catcher through a 96-in. connection leading to a set of four cooling towers 12 ft. in diameter and 72 ft. high. The cooling water is sprayed into these towers through numerous nozzles set in the sides. There is a set of towers for each furnace, the two sets being connected by means of an 84-in. header from the bottom of which the fans draw the gas for washing. The first-washed gas passes from the fans through a water separator into a 78-in. header called the first-wash main, from which it is passed back to the suction side of the fans working on second washing, these being shut off from the cooled-gas main. From these fans the gas passes through the separators and into the second-washed main of 60 in. diameter. The 60-in. main supplying the engines is connected to the middle point of this header.

28 The four cooling towers are carried on a structural platform about 30 ft. square and $18\frac{1}{2}$ ft. above yard level. This elevation provides clearance for the mud cars placed beneath to receive the drainage from the bottom connections. The connections between the towers are 8 ft. in diameter and the travel of the gas is up and down in alternate towers. Each tower is provided with a hopper bottom and pipe seal having connection with a common drain pipe which delivers the discharge of all four towers to the tank cars beneath. Towers *A* and *B* are further provided with emergency seal drains at a higher level. These emergency seals are normally idle, but should the bottom drain become clogged the tower will then drain through the emergency seal. Tower *A* is further provided with a suspended steel plate baffle in front of the 96-in. inlet opening. This arrangement when filled with water to the required height acts as a valve to shut off communication between the towers and the dry-dust catcher, a sealed overflow maintaining the proper water level when desired. The first tower is equipped with about 30 sprays, the second has 35, and the third and fourth about 20 to 25 sprays each. The sprays are placed in five circumferential rows, 6 ft. apart vertically. The lower row is about 20 ft. from base of tower. These towers are like those shown in Fig. 5 for furnaces 5 and 6. Several of the illustrations are of the gas washing plant for furnaces 5 and 6 which are similar to that of furnaces 3 and 4.

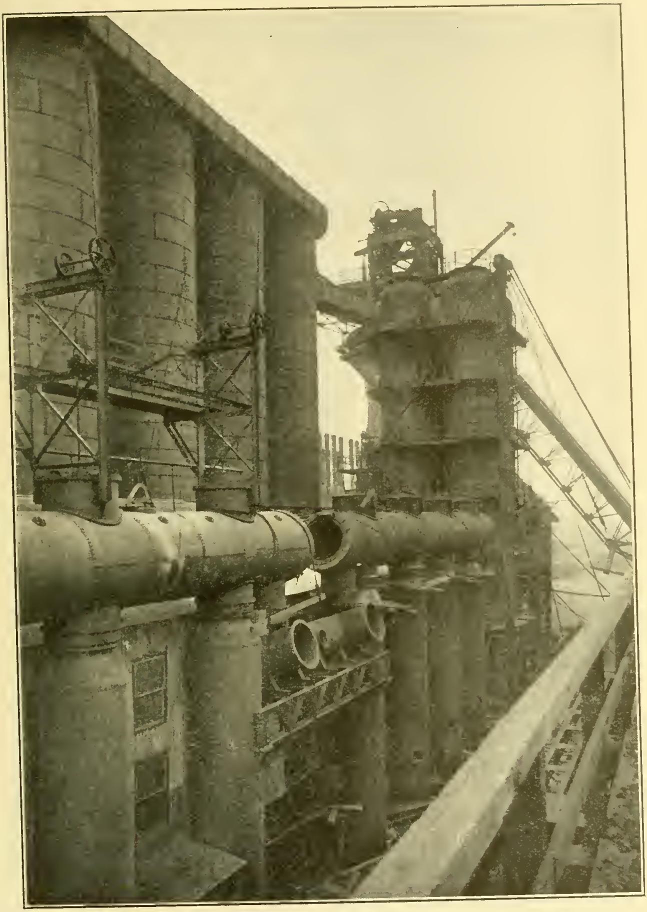


FIG. 5 GAS COOLING TOWERS AT FURNACES 5 AND 6

29 The sprays are supplied with water through three pipes rising from a ring main of 6-in. diameter near the base of the tower. Each spray is supplied through a 1-in. connection provided with a plug cock.

30 The standard nozzle, of brass throughout, is shown in Fig. 6. The shell has a 2½-in. external pipe thread which screws into a flange riveted to the shell of the tower. The helical passage produces a whirling cone-shaped spray of about 90 deg., and 6 to 10 ft. diameter. The 1½-in. plug provides convenient access to the spindle for cleaning. These sprays use about 7 gal. per min. at the average pressure carried.

31 From the towers the gas passes through a 7-ft. pipe to the fans. This pipe also is provided with nozzles which spray water into and against the approaching stream of gas, the nozzles being located at the center of pipe. The piping is well shown in Fig. 5.

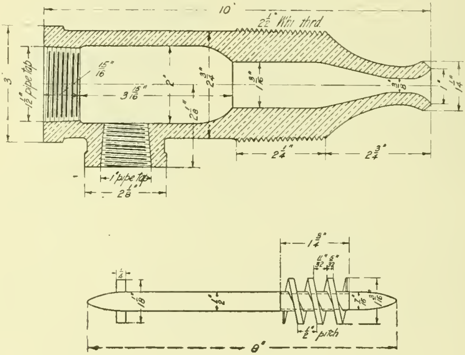


Fig. 6 Details of Spray Nozzle

32 The gas leaves the cooled-gas main at the bottom and passes to the fans through vertical suction connections. The latter have hoppers and water-sealed drains at the lower end and may be shut off from the cooled-gas main by means of bell valves operated by a winch and handwheels located on top of the horizontal main. These valves seat in a water seal. The opening is of 45-in. diameter. At the midpoint of the cooled-gas main connecting the two sets of towers is located a shut-off valve consisting of an inverted siphon which may be partly or wholly filled with water to regulate the amount of gas coming from either furnace.

33 The fan washers are housed in a steel frame building 150 ft. long, 29 ft. wide and 32 ft. high from yard level to eaves, equipped

with pitch roof and monitor, the covering being of corrugated steel. The building and machinery are carried on pile and concrete foundations. The center of fan-shafts is 9 ft. 5 in. above yard level, this elevation being necessary for drainage.

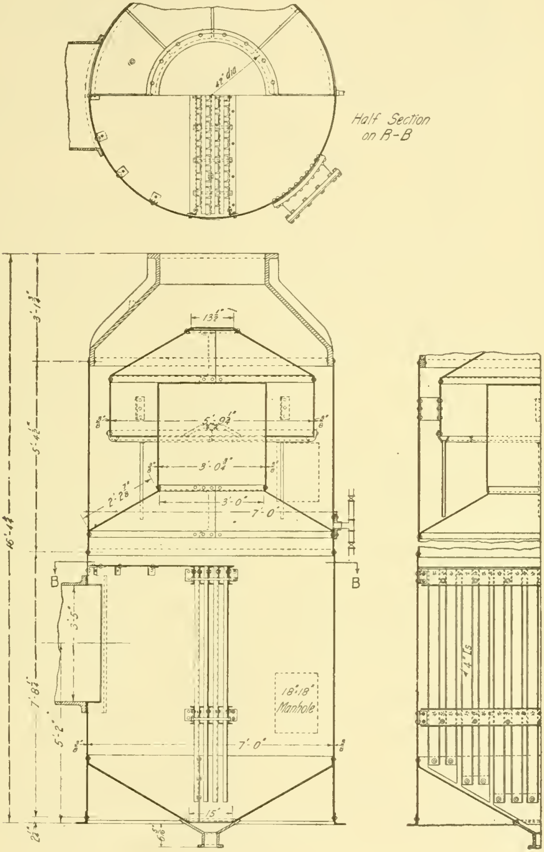


FIG. 7 WATER SEPARATOR FOR GAS WASHERS AT FURNACES 3 AND 4

34 There are eight centrifugal fans made by the Buffalo Forge Company. The wheels are of $\frac{1}{4}$-in. steel plate, 7 ft. 1 in. in diameter, having eight blades each $29\frac{1}{2}$ in. wide at the inner end, and $27\frac{1}{2}$ in. wide at the tip. Central opening of wheel is 40 in. in diameter.

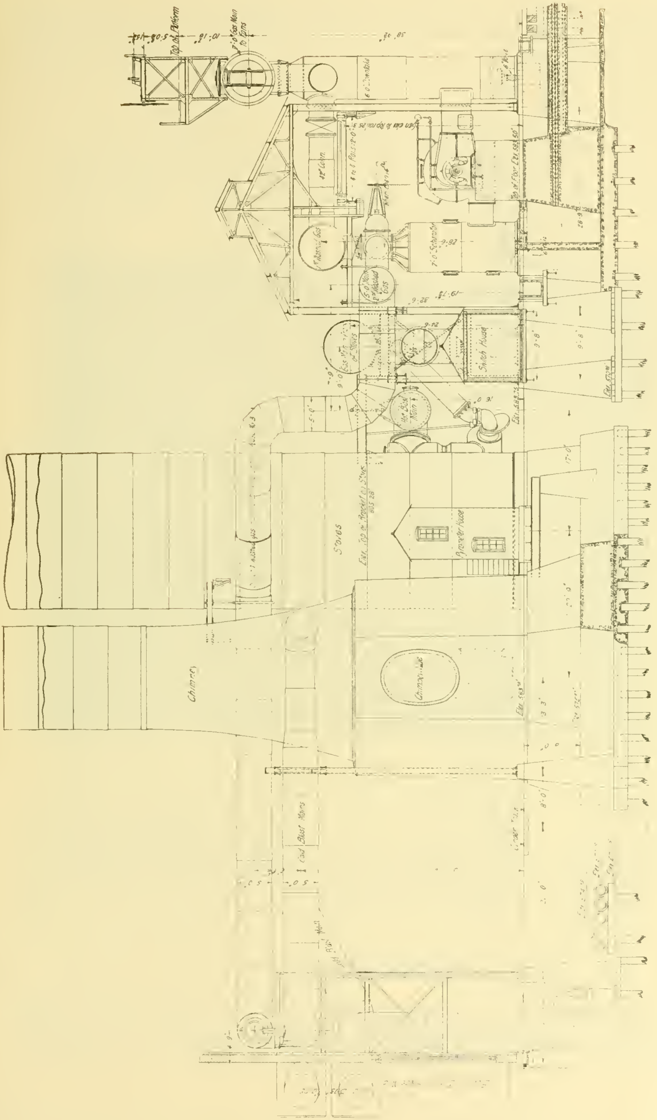
35 The casing is of cast iron and of the double suction type. It is made in sections, with machined joints bolted together for removal of wheel. Manholes are provided for cleaning and inspection. Each branch of the suction connection is rectangular 20 in. by 50 in., opening into the fan through a 36-in. diameter inlet. The bottom discharge connection is 40 in. by 36 in.

36 The wheel shaft of $6\frac{1}{2}$-in. diameter is direct-connected through a flexible coupling to a 100-h.p. motor operating at 480 r.p.m. Six of these motors utilize alternating current, the other two being for direct current. The two types are used so that should there be an accident to either circuit, the motors connected to the remaining circuit will continue to operate and keep a part of the engines running until the necessary corrections can be made.

37 Water is thrown into each fan through 16 spray nozzles. Eight of these discharge into the central inlet openings, four on each side; the other eight dischage into the fan through the upper half of its periphery. The sprays are fed by four $1\frac{1}{2}$-in. lines connected to a 6-in. header extending the full length of the building, over the fans. Each spray connection is a $\frac{3}{4}$-in. pipe. The water for the fan sprays is taken from the waste of bosh cooling water from the furnace, which overflows from a standpipe, a portion under the necessary head going to the fans.

38 From the fan the gas passes to a water separator constructed of steel plate 7 ft. in diameter by 13 ft. high. This separator is shown in Fig. 7. The gas passes first through a set of baffles consisting of four rows of 4-in. channels set vertically, the openings between the channels being $1\frac{1}{2}$-in. wide, with alternate or staggered spacing such that the streams of gas are broken and turned. The separated water falls down the vertical channels, carrying with it the dirt, and passes out at the bottom through a seal to the drainage system. After passing through the channel baffle, the gas rises through annular disc baffles and passes from the separator through a 36-in. top connection.

39 Each separator is equipped at the top with a cast-iron tee providing outlets through 36-in. gate valves respectively to first-washed and second-washed mains. Fans working on first washing discharge their gas into the first-washed main. This gas is then



General Arrangement Elevation of Gas Washers for Furnaces 5 and 6 taken by the fans working on second washing and by them discharged into the second-washed main. The diameters of the first- and second-washed mains are 78 in. and 60 in. The first-washed main

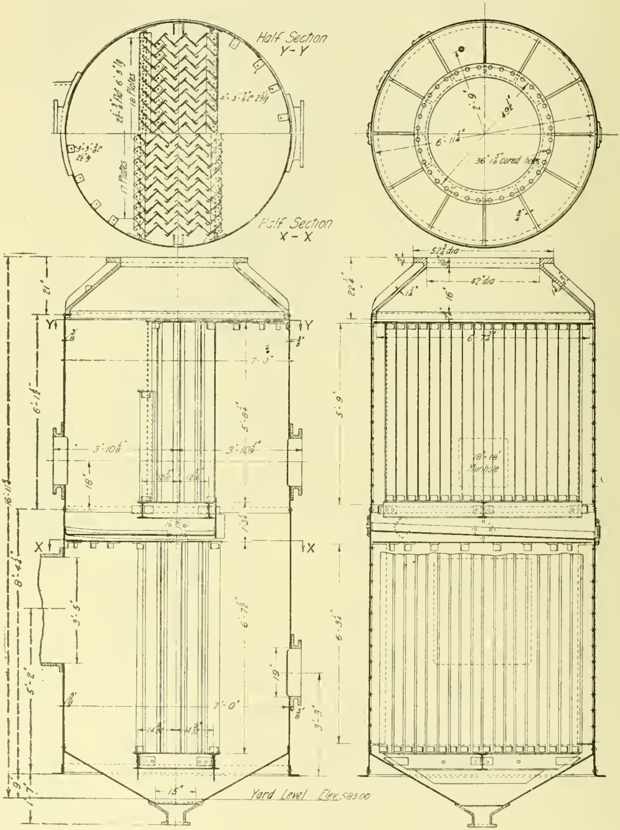


FIG. 9 WATER SEPARATOR FOR GAS WASHERS AT FURNACES 5 AND 6

extends full length of the fan house, and is connected to the vertical suction connection of each fan through a 42-in. gate valve. The valves and piping are so arranged that any fan may be operated on either first or second washing.

40 These gas washers are shown in sectional elevation in Fig. 8 and Fig. 10 shows the washed-gas main and fan connections in perspective.

41 The gas washing plant at furnaces 5 and 6 is substantially the same as that described for furnaces 3 and 4. The water separators have a different style of baffling. These separators are shown in Fig. 9. They are 7 ft. in diameter and 17 ft. high. The gas circulates through zigzag passages formed by narrow plates assembled as shown. The projecting edges of plates are formed to catch the water and lead it to the bottom of the chamber, where it passes out through a seal. There are two sets of baffles through which the gas passes in succession, one at the bottom and one at the top.

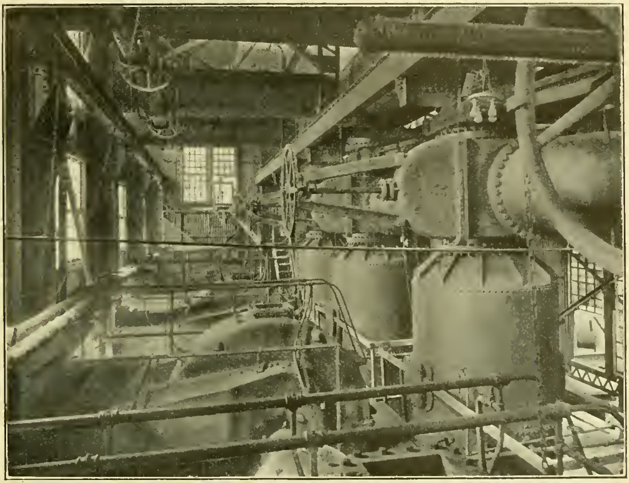


Fig. 10 No. 5 Gas Washer Fans and Piping

BLOWING-ENGINE HOUSES

42 As previously stated the blowing engines are located in two buildings, blowing-engine house No. 2 and No. 3, each substantially

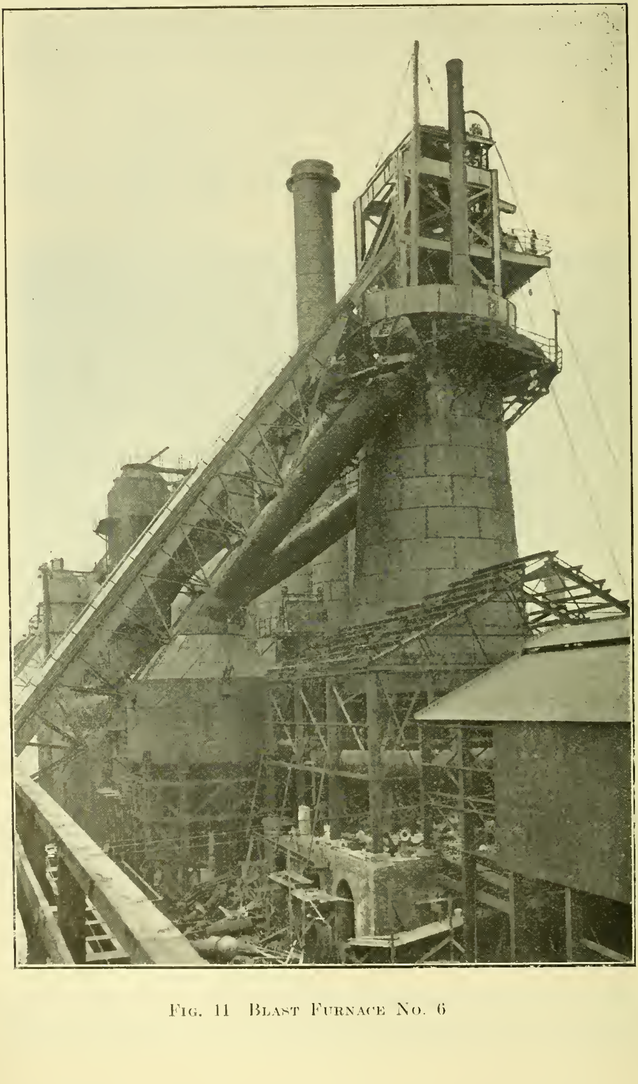


FIG. 11 BLAST FURNACE No. 6

alike in design and arrangement. Each blowing-engine house contains eight air-compressing units (Fig. 13), each unit having a capacity of about 20,000 cu. ft. of free air per min. when operating at 65 r.p.m.

43 The gas engines, built by the De La Vergne Machine Company of New York, are coupled to vertical blowing engines, built by the Southwark Foundry and Machine Company of Philadelphia.

44 Each building is 425 ft. long. A basement 10 ft. deep provides space for piping, oiling system, etc. A steel skeleton frame supports the roof and runways for a 35-ton electric traveling crane. The walls are of brick, and the roof of corrugated iron sheathed inside with wood. Air enters through louvers located in the east wall at intervals of $12\frac{1}{2}$ ft. The flooring is of $\frac{5}{16}$-in. checkered steel plate laid on 10-in. beams. Two cold-blast mains, one for each furnace, extend the entire length of building, and arrangements are such that any of the eight engines can deliver to either of the two cold-blast mains. The piping is so arranged that the north engine in blowing-engine house No. 2 can deliver to furnaces 1, 2, or 7. There is also an auxiliary blast main connecting blowing-engine houses Nos. 2 and 3 in such manner that steam-driven blowing engines may deliver to any one of the seven furnaces, when required.

45 The exhaust gases, jacket water, etc., are discharged into an underground tunnel or header located about twelve or fifteen feet east of the building and parallel to it. This tunnel is provided with two outlets, one into the general drainage conduit, and the other to the atmosphere through a brick-lined steel stack located at mid-point of exhaust tunnel. The exhaust tunnel is also provided with sixteen laterals, one opposite each engine cylinder, and extending only to the outer surface of the concrete foundation wall of the building. These details are shown in Fig. 12.

46 The tunnels are of horse-shoe section of reinforced concrete, supported on piling. The main tunnel is 10 ft. 2 in. high, 6 ft. wide at the bottom, with a semicircular roof 8 ft. in diameter. The eight laterals are about 8 ft. 2 in. high and 4 ft. wide.

47 The ventilating stack is 10 ft. diameter of steel plate lined with red brick to 9 ft. 2 in. diameter.

48 Located between the discharge chamber of each blowing cylinder and the cold-blast main, is a non-return valve. The discharge chamber may be connected to the atmosphere through a pipe extending through the building wall and controlled by a gate valve. This atmospheric connection is opened when it is necessary to start with

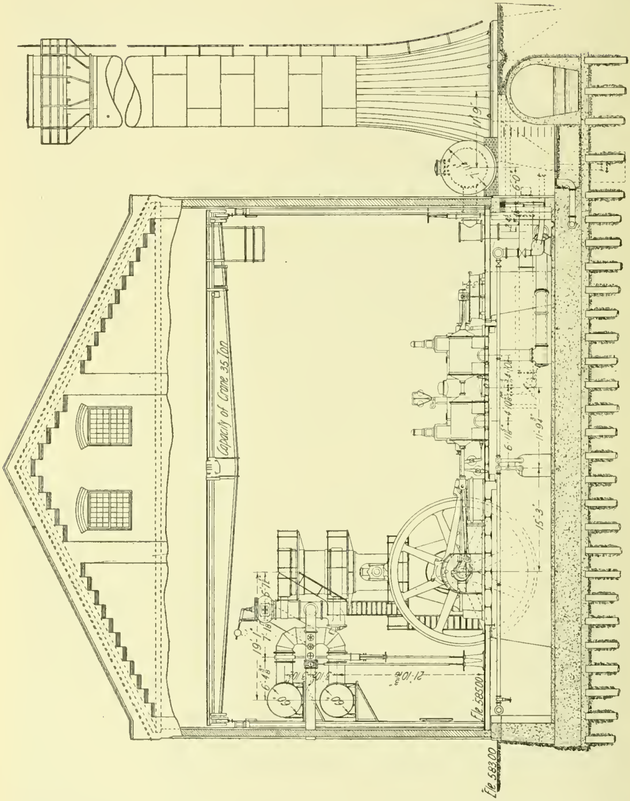


Fig. 12 General Arrangement of Blowing Engine-House No. 2

compressed air. When operating conditions have been established in the motor cylinders, the gate valve is closed and the non-return valve rises from its seat for delivery into the blast main.

49 Gas is delivered to each engine from the main header located outside the building through a 24-in. branch, including a standard 24-in. gate valve just inside the building wall and above floor level. The 24-in. pipe then turns downward to the basement floor where it divides into two 18-in. branches, one to each gas pump. The air pumps draw their supply from the basement through short connections passing through the floor.

50 The cast-iron exhaust pipe for each cylinder is 22 in. in diameter. It is attached to the bottom of the cylinder, descends vertically about six feet and then extends horizontally to the east wall of the building and into the lateral tunnel above noted. A tee outlet or double discharge is furnished on the end of each exhaust pipe. A gate valve is provided.

51 During operation water is injected into each exhaust pipe through spray pipes located just below the cylinder. This keeps the pipe cool, partially muffles the exhaust, and prevents explosions in the exhaust piping.

52 The cooling water for the engines is taken from a 12-in. main extending the full length of the building on the east side of the basement. A 10-in. reserve main is installed on the west side. Opposite each engine is located an 8-in. connection with valve. From this connection a 6-in. branch leads to each side of the engine. The supply of water for each engine is thus controlled by one valve.

53 As originally installed, cylinders, pistons and muffling sprays were all supplied with water through individual connections, each wasting to a sewer. The system has since been modified such that the water passes through piston, cylinder heads, cylinder jackets and muffling sprays in the order named. A small portion of the water only is used by the muffling sprays.

54 Thermometers are placed to indicate the temperatures of water leaving the piston and cylinder jackets. The jacket water leaving each cylinder head discharges upward through a vertical pipe provided with a return-bend discharge nozzle. The water leaving the nozzle discharges downward into a funnel leading to the cylinder jacket, the stream thus being in full view of the operator.

55 Compressed air for starting is supplied through a 5-in. branch from a 6-in. main delivering air from power house No. 1. The 5-in. connection divides into two $3\frac{1}{2}$-in. branches, one to each side of the engine where it connects with the starting valve.

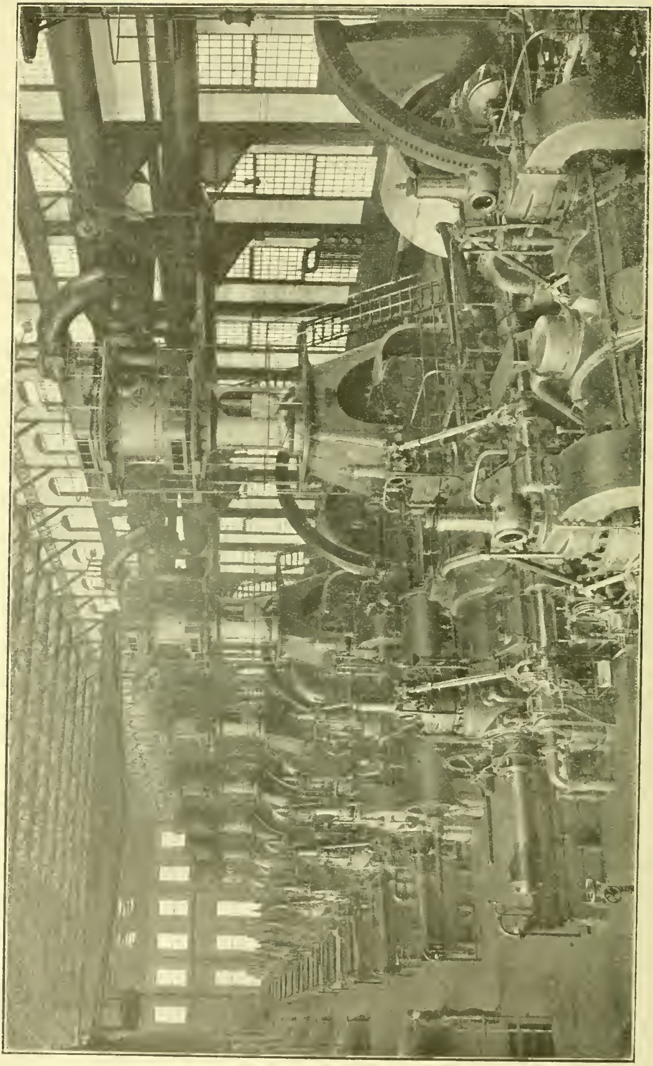


Fig. 13 Interior View of Blowing-Engine House

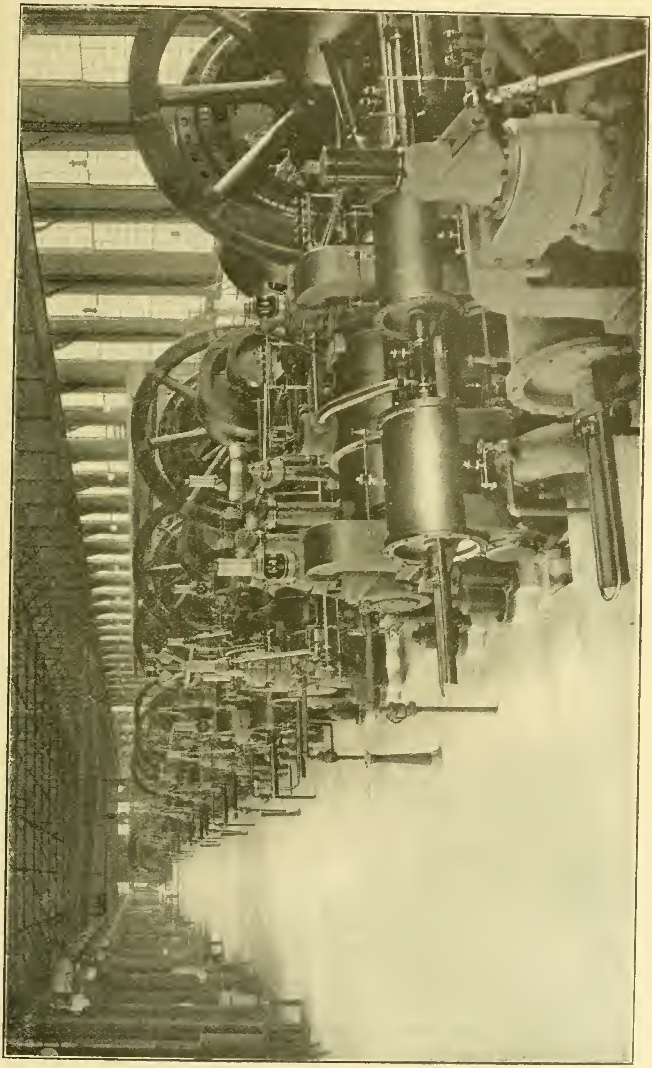


FIG. 14 INTERIOR VIEW OF POWER HOUSE

OILING SYSTEM

56 An oiling system of the gravity type is installed at each blowing-engine house. Two 500-gal. storage tanks are located near the roof from which the oil is piped to the sight-feed connections on the engines. A complete system of drip pans and oil catchers is provided at the engines. From the pans the oil drains to the basement, and passes first through a gravity separating tank where most of the water is removed. The oil then flows over a heating device where its temperature is raised to about 120 deg. fahr. and it then passes through settling tanks and weir boxes, where the remaining water and nearly all of the suspended matter are deposited under the action of gravity. From the weir boxes the oil passes into White Star filters, and thence by means of a duplex steam pump to the storage tanks located near the roof.

57 The above description applies to the system used for supplying oil to parts of the engine where the oil is but slightly contaminated by foreign matter. At certain other points of lubrication, such as the gas pump and motor piston rods, etc., the return oil is contaminated to a considerable degree by flue dirt. A separate system very similar in principal to the one already described is installed to take care of these parts.

58 The buildings are heated by means of the forced circulation of hot water through radiation piping. The piping extends entirely around the building and the water which is heated by exhaust steam, is circulated by means of a centrifugal pump.

POWER HOUSE

59 Eight units for developing electric power, each rated at 1000 i.h.p., are located at the south end of power house No. 1 and occupy a space 350 ft. long. The engines are direct connected to 500-kw. generators, four of direct current, 250 volts, and four of three-phase 25-cycle alternating current, 440 volts. The total length of the building is 725 ft., the width 77 ft. and the height from the floor line to the bottom chord of the roof truss 35 ft. A steel skeleton frame supports the roof and crane runways. A basement 8 ft. deep is provided and a concrete matte, on piling 83 ft. wide by 4½ ft. thick, supports the building and machinery. An interior view of the power house is shown in Fig. 14.

60 The floor is of concrete reinforced with expanded metal, resting on I-beams. Cast-iron gratings between the engines ventilate the basement.

61 The switchboard is placed on a platform 213 ft. long at the east side of the building. A controlling panel is provided for each generating unit. Numerous feeder panels control the various mill circuits. The alternating-current switches are located at the south end of the board, and the direct-circuit control at the north end.

62 The engines exhaust into the main drainage tunnel and a steel stack 5 ft. in diameter and 60 ft. high carries away the gases and vapor.

63 Each engine takes gas from a 30-in. main outside the west wall of the building through an 18-in. connection controlled by a gate valve; this 18-in. connection divides into two branches, one going to each gas pump. A throttle valve controlled by a Tolle governor and placed as close as possible to the valve chest of its respective gas pump, is located in each of these branches.

64 The air pump draws its supply from the basement. Compressed air for starting is provided through a 6-in. main extending the entire length of the plant. There is a 4-in. branch at each engine.

65 The cooling water is supplied from the general yard service through a 6-in. main with branches at each engine.

66 Each motor cylinder is provided with a separate exhaust pipe of 16-in. diameter exhausting directly into the tunnel. Water is sprayed into the pipe to cool and muffle the exhaust.

KOERTING TWO-STROKE CYCLE ENGINES

67 The engines were designed by the firm of Koerting Brothers, Hanover, Germany, and were built by the De La Vergne Machine Company, New York. They are of the two-stroke cycle double-acting twin cylinder type.

68 The blowing-engine units have motor cylinders 38½ in. in diameter by 60-in. stroke, and occupy a floor space of 40 ft. by 52 ft. The engines for electric generating have cylinders 24¾ in. in diameter by 43⅜-in. stroke and occupy a floor space of 32 ft. by 36 ft.

69 The cycle of operation with reference to the motor cylinder is as follows: Gas and air are compressed in separate pump cylinders to a pressure of about 10 lb. per sq. in. above atmosphere. The gas and air meet in the mixing chamber above the inlet valve of the

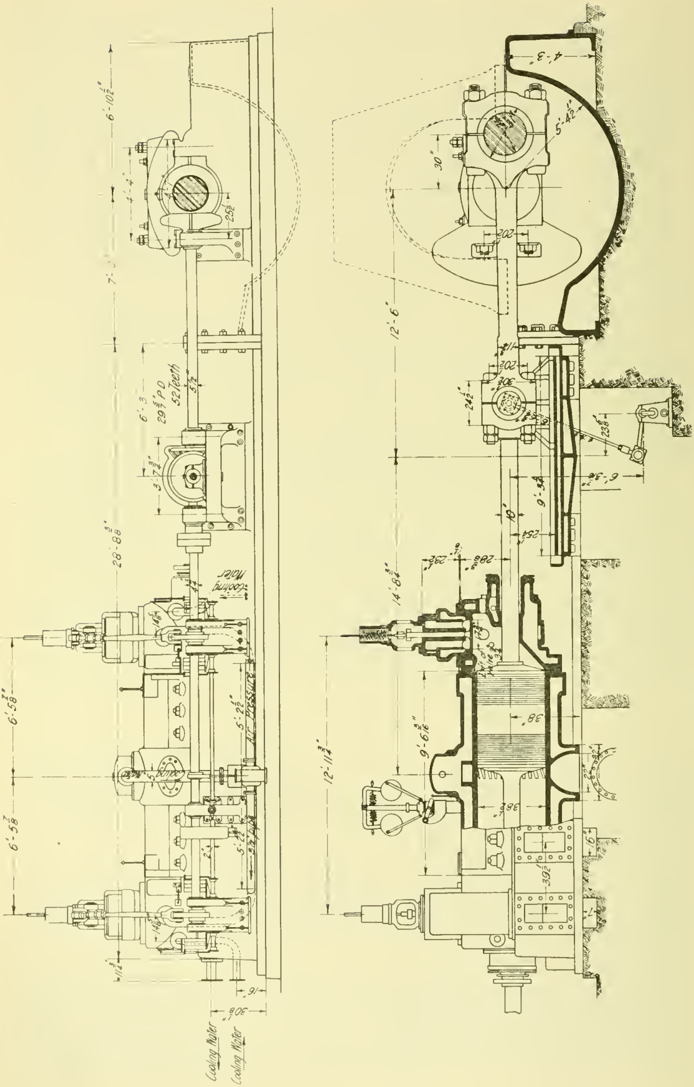


FIG. 15a GENERAL ASSEMBLY ELEVATION OF 2000-H. P. ENGINES

motor cylinder. During the period when the motor piston is at and near the outer end of its stroke, the inlet valve opens, admitting first the scavenging air and second the mixture to the motor cylinder. During the return stroke of the piston the charge is compressed to a final pressure of about 150 lb. gage.

70 Ignition by electric spark takes place somewhat prior to the completion of the compression stroke. Near the end of the expansion stroke, the piston uncovers the exhaust ports through the cylinder walls. The opening of the inlet valve occurs very soon thereafter, and the new incoming charge forces the burned gases out through the exhaust ports completing the cycle.

71 The general plan and elevation of the 2000-h.p. engine is shown by assembly drawings in Fig. 15*a* and Fig. 15*b*. The smaller engines are very similar in general design.

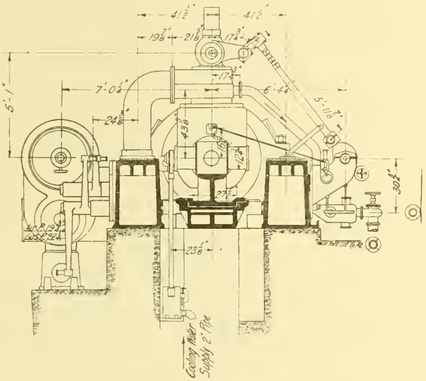


Fig. 15*b* End Elevation of 2000-h.p. Engine

72 Each unit is composed of two separate engines each complete in itself with the exception that the crankshaft is common to both.

73 The main frame for each side is composed of two heavy cast-iron box girders. The motor cylinder is supported on and between these at one end. The shaft bearings are formed in the other end of the frame.

74 At one side are the gas and air pump cylinders. The two pistons are mounted on a single piston rod and driven by an overhung crank on the outer end of the crankshaft.

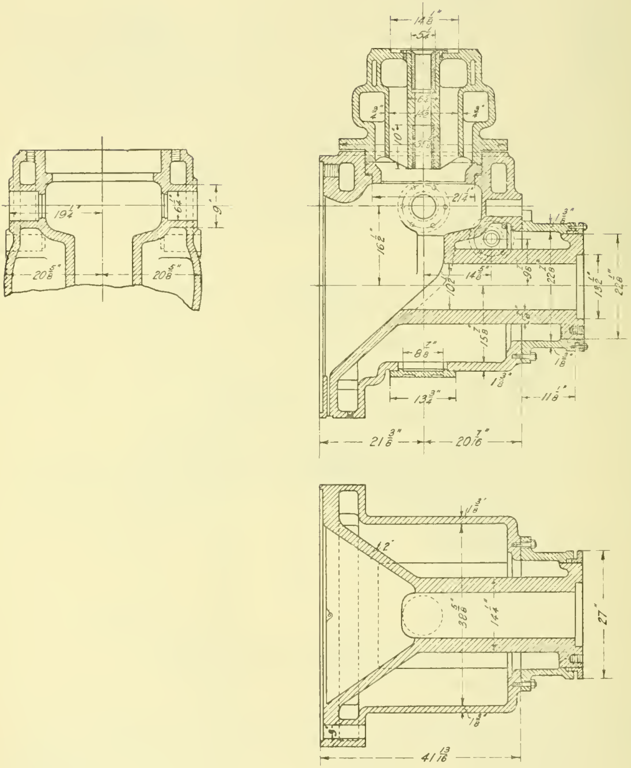


Fig. 16 Details of Cylinder Heads and Inlet Ports

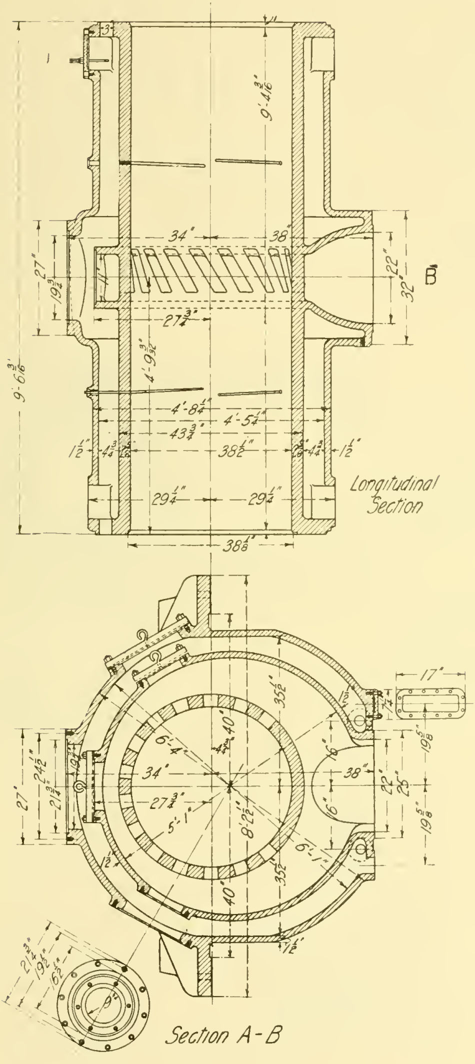


Fig. 17 Details of Motor Cylinder

75 The pump valves are of the piston type, smooth cylinders without packing of any kind, and are driven by eccentrics on the crankshaft. The induction valve for the gas pump is open during about 145 per cent of its suction stroke; that is to say, during the entire suction stroke as well as the first 45 per cent of the discharge stroke. The air pump discharges during nearly its entire stroke, the object being to provide scavenging air for the motor cylinder prior to the entrance of the mixture. The gas and air pass from their respective pumps through ducts to a mixing chamber above the motor inlet valve. The prior discharge action of the air is intended to force the gas column back into its duct, prior to the opening of the motor inlets, in such manner that scavenging air is provided in advance of the mixture.

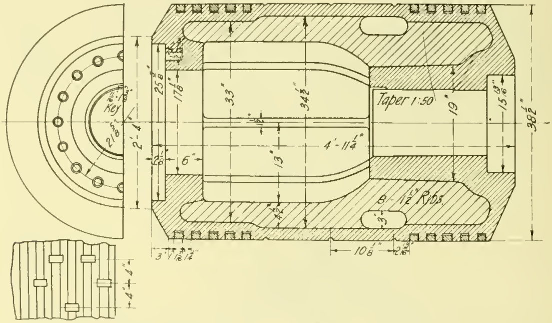


Fig. 18 Details of Motor Piston

76 The motor cylinders are of cast iron in one piece with water jacket and exhaust passage. The cylinder heads (Fig. 16) are of cast iron with water jackets and are provided with an expansion joint. Fig. 17 shows a 38½-in. motor cylinder in detail.

77 The piston is of cast iron, nearly as long as the stroke because of its action as an exhaust valve. Five grooves are provided at each end, equipped with dowells in such manner that the five snap rings are held with their openings near the bottom of the cylinder. The piston (Fig. 18) resting on the cylinder wall closes the opening through the ring and prevents leakage and possibly premature ignitions. Cooling water is supplied through the hollow rod by means of swinging connections shown in Fig. 19.

78 The crosshead is of the slipper type babbitt faced. The marine type connecting rods are forked at the crosshead end. Bear

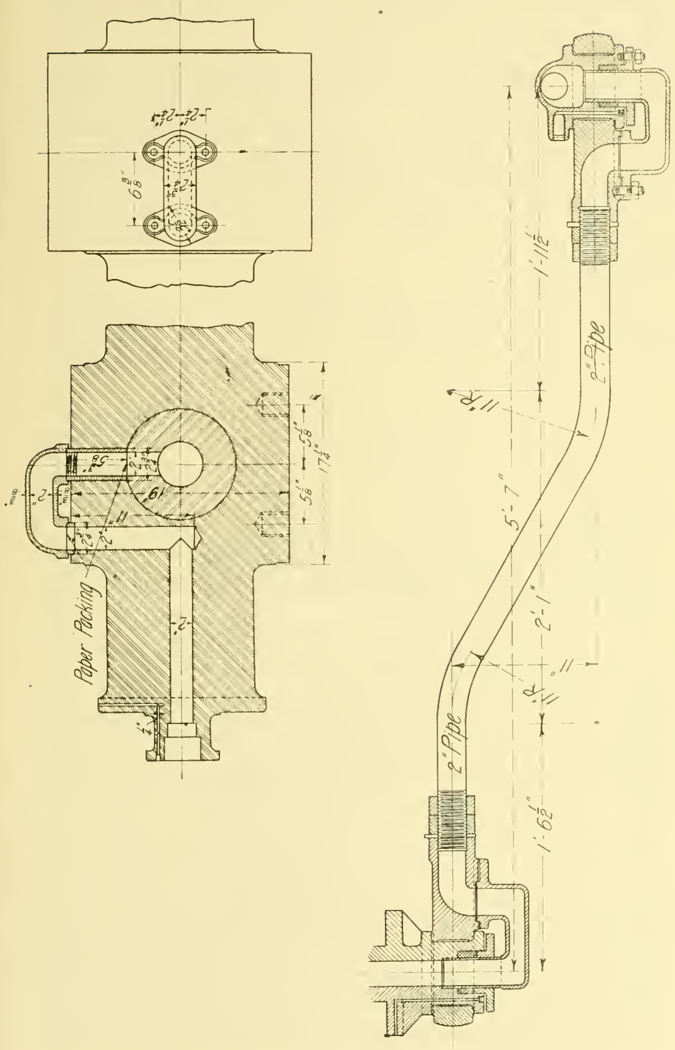


Fig 19 Details of Water Connection for Piston Rod

ings are split shells, babbitt lined for the crank and phosphor bronze for the crossheads, held by bolted caps.

79 The crankshaft for the 2000-h.p. engine is of the built-up type and is carried by four bearings. Each crank pin is carried by two forged steel webs between its pair of main bearings and to these webs are bolted the counterweights. Each end of the shaft projects beyond its outboard bearing and carries a crank and eccentrics for the gas and air pumps. The shaft for the 1000-h.p. engine is a single forging, being in other respects similar to that for the 2000-h.p. engine. All of the principal forgings were made at the Krupp works in Germany.

80 The flywheels for the 1000 h.p. engines are 17½ ft. n diameter and weigh 45,000 lb. The wheels for the 2000-h.p. engine are of 20 ft. diameter and weigh 65,000 lb. The wheels were cast in halves, and the fastenings are steel links shrunk into place at the rim and bolts at the hub.

81 The inlet valves are steel forgings of the mushroom type located in casings at the top of the cylinder heads. They are opened by cams located on a shaft parallel to the axis of the motor cylinder and driven by bevel gears from the crank shaft, and closed by strong helical springs.

82 Ignition is by means of electric spark of the break or arc type, with two igniter plugs in each cylinder head. The electric current is furnished by magnetos, one for each plug. The current is produced in the following manner: The magneto armature is first slowly rotated in opposition to the force of a spring through an angle of about 30 deg. from its initial position. It is then released and under the action of the spring executes a rapid return motion or oscillation. During this return motion the igniter terminals are mechanically separated and the arc formed, the motion of the armature being transmitted to the plugs through cranks and reach rods for this purpose. The magnetos are now being discarded in favor of a direct-current system of ignition of simple form.

83 The timing of the ignition is accomplished by means of the igniter shaft connected to the cam shaft through a helically slotted sleeve and a pair of spur gears. By sliding the sleeve along the shaft, the phase of the igniter shaft is advanced or retarded. One of the spur gears is provided with sufficient width of face to accomplish the required range of movement. The sleeve and hub form a triple threaded screw and nut, and have proved very satisfactory in operation. The apparatus is shown in Fig. 20. The equivalent device

furnished by the makers consisted of a single spiral slot and feather which proved defective in wearing qualities.

84 The regulation of the 1000-h.p. units is by a butterfly throttle valve under the control of a Tolle governor. The strength of these governors is about 2000 lb. The throttle valve is located in the gas supply pipe of each pump, as close as possible to the pump.

85 The 2000-h.p. engines are regulated by means of bypass valves located at the gas pumps, and under the direct control of an adjustable-speed oil-pressure governor. Each gas pump, in addition to its original distributing valve, is provided with a reciprocating bypass valve, driven from the pump valve-gear. This valve is of the hollow plug type turned to a working fit in its valve cylinder bushing, and is provided with ports through the walls of the hollow plug. Corresponding ports through the walls of the valve cylinder bushing communicate respectively with A, the gas pump discharge passage, and B, the gas pump clearance. Two respective leakage paths are thus formed through which a portion of the gas is bypassed back into the supply pipe of the gas pump. The hollow plug valve of the bypass is arranged for partial rotation on its axis under control of the governor, and the angular position of the plug valve determines the degree of opening of the bypass ports, which in turn governs the quantity of gas returned to the pump supply pipe. Due to the con-

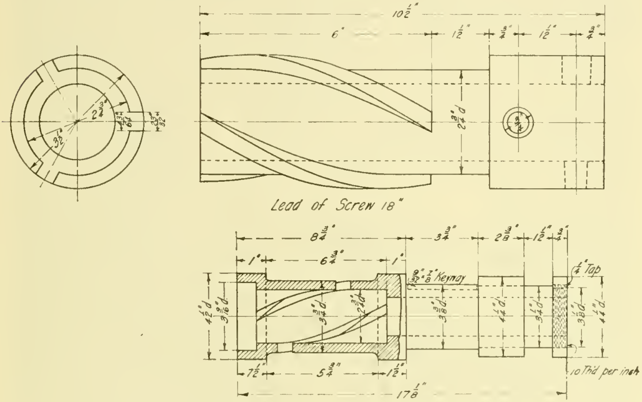


Fig. 20 Screw and Nut for Igniter Shaft

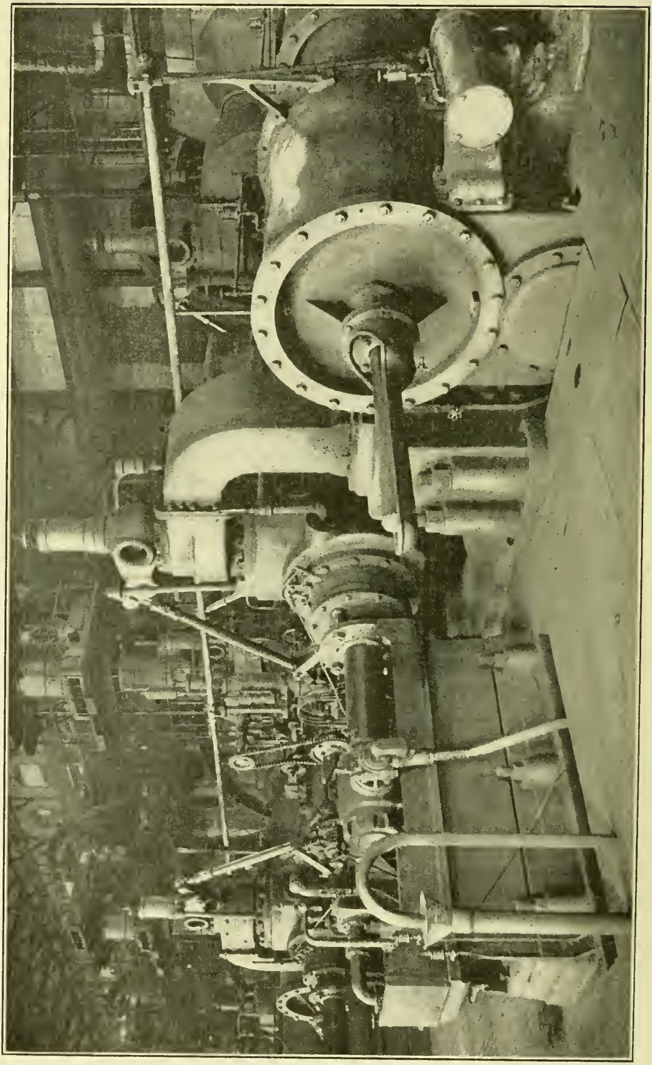


FIG. 21 GENERAL VIEW OF GOVERNING APPARATUS FOR BLOWING ENGINE

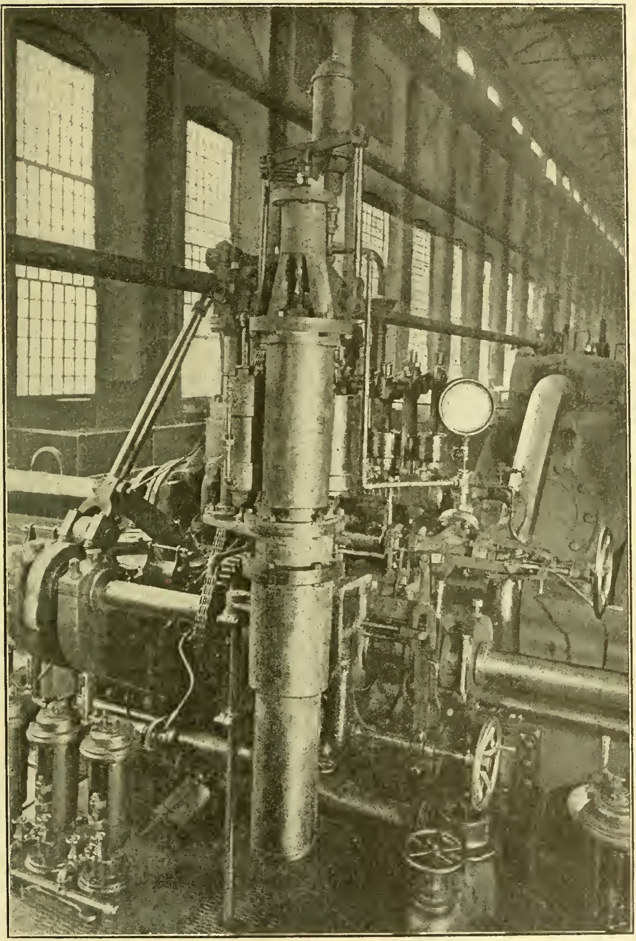


Fig. 22 General View of Oil-Pressure Governor

struction of the main pump valve, bypassing from the passage *A* can occur only during the suction stroke of the pump, the bypass port being connected to a chamber which communicates with the pump discharge passage only during such suction stroke. The bypass port from the pump clearance allows bypassing to occur during the discharge stroke of the pump.

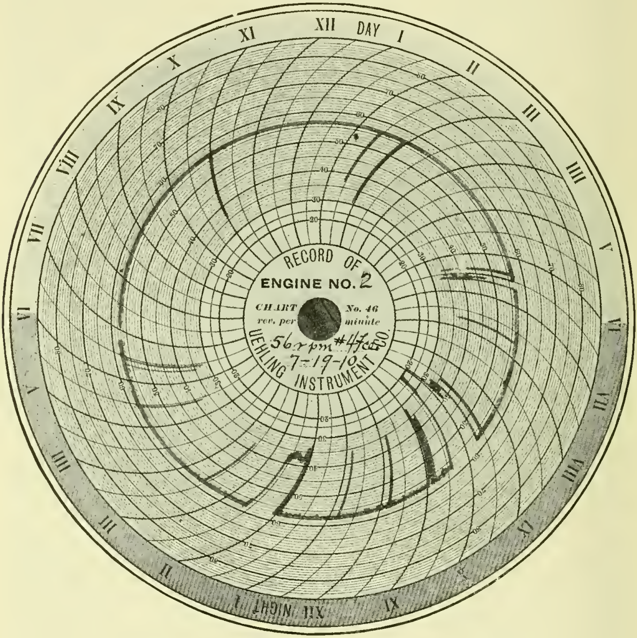


FIG. 23 SPEED CHART—REVOLUTION RECORDER

86 When the governor is in the position corresponding to maximum power demand, both bypass ports are closed. As the demand for power decreases, the port from passage *A* is first opened, the port *B* remaining closed. With a further decrease of power demand port *B* also opens. The port *A* is arranged for prior opening for the purpose of removing the gas from the vicinity of the motor inlet at and

during the scavenging period. The full opening of both bypass ports is sufficient to limit the engine speed to about 45 r.p.m. under conditions of friction load. The reciprocating motion of the valve is provided for the purpose of preventing accumulation of dirt on the valve surfaces, thus preventing any undue resistance to rotation under the action of the governor. The general arrangement of the bypass valve gear is shown in Fig. 21.

87 The governor is of the adjustable-speed oil-pressure type, controlling the valves directly by means of a piston of $4\frac{3}{16}$ in. in diameter operating differentially against the force of a spring. The total tension of the spring is about 830 lb. A $3\frac{3}{4}$-in. by 3-in. single-acting triplex oil pump is driven by means of a 2-in. Renold silent chain from the cam shaft of the engine. The oil is discharged through a $\frac{1}{2}$-in. orifice of special design, the area of which is controlled by a needle valve. The motion of the small piston is transmitted by levers, shafting, and reach rods, and controls the angular position of the bypass valve. The needle valve is linked to the timing device of the igniter mechanism in such manner that the time element or lag of the igniter is neutralized, the ignition remaining constant at all speeds.

88 The speed variation between the extremes of travel is 4 per cent. The energy required to drive the pump amounts to about 0.6 h.p. The valve gear, governor, and timing device were designed by the author with the assistance of Mr. Hugh Boyd and the entire apparatus was constructed in the shops of the steel company.

89 The general arrangement of the governor is shown in Fig. 22 and a chart from the Uehling revolution recorder in Fig. 23. The speed depressions recorded in the latter indicate periods of casting and checks at the furnace.

90 Positive lubrication of the motor cylinders is accomplished by force-feed pumps of the screw-press plunger type. These pumps are driven by lever and ratchet, operated by cams located on the engine cam shaft. The oil pump cams are located in such manner that the oil injection occurs during each compression stroke of the motor piston. There are three oil inlets for each end of the motor cylinder, one at the top and one at each side near the bottom. An individual screw plunger serves each oil inlet which is provided with a check valve.

KOERTING ENGINES

Item	Electric Power	Blowing Engine
Rated h.p.	1000	2000
Speed, r.p.m.	100	35 to 65
Diameter, motor cylinder	$23\frac{3}{4}$	$38\frac{1}{2}$
Stroke, motor cylinder	$43\frac{3}{8}$	60
Diameter, gas pump	$28\frac{3}{4}$	$45\frac{1}{4}$
Diameter, air pump	$25\frac{3}{4}$	$38\frac{1}{4}$
Stroke of pumps	$33\frac{1}{2}$	$49\frac{1}{4}$
Main journals	Four $12\frac{5}{8} \times 23\frac{5}{8}$	Two 18×33 One 22×40 One 22×35
Maximum shaft diameter	$18\frac{1}{2}$	26
Length of shaft	26 ft. 6 in.	34 ft. $7\frac{1}{2}$ in.
Crank pins	Two $12\frac{5}{8} \times 13\frac{3}{4}$	One 24×16 One $18 \times 19\frac{1}{4}$
Crosshead pins	Four $8\frac{1}{4} \times 7\frac{7}{8}$	Four $12\frac{3}{4} \times 11\frac{1}{2}$
Piston rod	$6\frac{5}{16}$	10
Crosshead shoe	$19\frac{3}{4} \times 36\frac{1}{4}$	$27\frac{1}{2} \times 52$
Connecting rod	9 ft. $\frac{1}{4}$ in.	12 ft. 6 in.
Diameter, connecting rod		
Large end	$8\frac{11}{16}$	$12\frac{1}{2}$
Small end	$7\frac{1}{8}$	10
Pump piston rod, diameter	4	$5\frac{1}{2}$
Pump crank pin	$4\frac{5}{16} \times 5\frac{1}{2}$	$6\frac{1}{4} \times 8$
Cam shaft, diameter	$3\frac{1}{8}$	$4\frac{3}{4}$
Motor inlet valve, diameter	$12\frac{5}{8}$	$18\frac{3}{4}$
Gas pump inlet valve, diameter	13	18
Air pump inlet valve, diameter	12	18
Exhaust pipe, diameter	$15\frac{3}{4}$	22
Flywheel, diameter	17 ft. 6 in.	20 ft.
Flywheel weight	45,000	65,000
Blowing cylinder, diameter	—	76
Blowing-engine, stroke	—	60

GENERAL NOTES RELATING TO OPERATION

91 Both gas-cleaning apparatus and the gas engines were installed at an early stage in the history of the art and are necessarily imperfect when compared with modern examples to which have been applied those essential refinements that can be gained only through experience. The average dust content of gas as delivered to the second-washed main amounts to about 50 to 80 mg. per cu.m., equivalent to from 0.022 to 0.035 grains per cu. ft., which would rightly be

considered bad practice in modern gas-cleaning plants. It therefore is fortunate that the type of engine selected is able to operate perfectly well when supplied with this imperfectly cleaned gas, without any distress whatever.

92 Nevertheless, operation of the character named cannot be claimed for the first three years. The author believes, however that esssentially all of the trouble can be traced to several major causes tending to produce premature combustion and a number of minor details not well appreciated at that time.

93 The conditions tending to produce premature combustion and attendant failure of parts subject to the resulting high pressures and temperatures were: imperfect piston packing which was neither properly dowelled nor provided with keepers; unsuitable oil used in the motor cylinders; and high hydrogen content in the gas. Minor causes of premature combustion were: projecting portions of parts exposed to the fire; and accumulations of flue dirt which, in combination with the oil, baked on the surfaces of the parts; the projecting portions remaining incandescent and initiating premature combustion. Minor troubles were also due to various causes, such as wet gas which fouled the igniter points with its accompanying flue dirt; dirty gas which clogged the valves of the controlling devices, making the speed control more difficult; imperfect rod packing, etc., which produced bad atmospheric conditions in the building; inadequacy of certain parts of the 1000-h.p. engines subject to high inertia stresses at 100 r.p.m., etc.

94 Rectangular dowells are now applied to the piston grooves in such secure manner that the openings through the snap rings are confined to a location near the bottom of the cylinder, thus preventing leakage through the openings. The cylinder oil now used does not leave a carbonaceous residue of any considerable magnitude. The pressure of water supply to tuyeres, coolers, and bosh plates is maintained slightly lower than the internal pressure of the furnace; hence cool water cannot enter the furnace to produce excessive hydrogen, following puncture of these parts.

GAS-CLEANING AND SUPPLY SYSTEM

95 As previously noted, there are three gas-cleaning plants, one for each pair of furnaces; and the three delivery mains therefrom are interconnected by means of pressure-equalizing pipes, two in number. These mains for hot gas, cooled gas, and washed gas are locally inter-

connected in parallel relation at each pair of furnaces. It is therefore possible to control the amount of gas taken from each furnace and the gases from the two furnaces are thoroughly mixed by discharging into a common washed-gas delivery main. In order to promote in the best manner uniformity in the constitution of the gas, the delivery from the several washeries should then discharge into a common distributing main or holder. Referring to Fig. 1, however, it will be noted that the locations of the three delivery mains, and the relative locations of the two equalizing pipes are such that it is impossible for such mixing to occur even locally or approximately. A partial solution constituting a great improvement would consist in relocating the 30-in. delivery pipe from washers Nos. 1 and 2 along the west wall of blowing-engine house No. 2, to form a junction at the southwest corner of that building with the 60-in. delivery main from washers Nos. 3 and 4. Also the 36-in. equalizing main should deliver gas into the 60-in. delivery main from washers Nos. 5 and 6, instead of into the north end of the 96-in. header at blowing-engine house No. 3. Power house No. 1 and blowing-engine house No. 2 would then receive the average of gas from four furnaces, whereas at present blowing-engine house No. 2 receives gas only from furnaces 3 and 4, and at power house No. 1, the four north engines may receive gas from furnaces 1 and 2, and the four south engines from furnaces 3 and 4. Under these conditions of piping, the gas supply at any point is but an average of that from two furnaces. and at times the irregularity is considerable, the thermal value occasionally varying between limits of 105 and 80 B.t.u. per cu. ft.. within a period of a few seconds.

96 Owing to the fact that hot gas mains of the three pairs of furnaces are not interconnected, the danger of explosion due to the entrance of air is enhanced to a certain degree, especially when but one furnace of any pair is in operation. This danger is minimized to some extent by means of the equalizing connections between the several washed-gas delivery mains, and the remaining conditions are provided for through the skill and watchfulness of the operators, who are greatly assisted in their work by a system of local telephones, and by indicating and recording vacuum and pressure gages connected at the proper points. Such conditions, however, occur only during checks and casts at the furnace, or in case of failure of the cooling water supply. Such periods are easily taken care of by the operators who thoroughly appreciate the situation. The principal precaution consists in sealing off the connection between towers and dust catcher, before the wind

is taken off the furnace, one furnace of the pair being assumed already out of service. The fans are also shut down or bypassed, and the fan connections sealed off when necessary. there being a diaphragm seal at the suction connection of each fan washer. The most probable point for entrance of air into the system is through the furnace top and connections.

97 Pressure gages are provided at each washer as follows: There is a recording pressure gage for the second-washed main, a recording vacuum and pressure gage for the cooled-gas main, and a manometer connected to tower *D*, Fig. 3.

98 Dirt accumulates on the domes, and on the walls near the tops of towers *A* and *B*, especially during the winter months. The falling of these accumulations, if not otherwise known, is announced by the appearance of overflow water at the emergency seal, due to the closure of the normal outlet for dirt and water at the bottom of the tower. The accumulation at the bottom is then broken up by pokers inserted through the gate valves and pipe tees provided at the bottom drain connection of each tower for that purpose. This occurs on an average of twice a month and occasionally twice a day. These accumulations are largely due to the fact that there is not sufficient pressure to furnish water to the upper three rows of nozzles which are consequently inactive: the dome and upper walls are therefore not washed by flowing water, and the dirt accumulates. The accumulation of dirt in the fan washers and their connections is practically negligible. The water separators require cleaning once, occasionally twice a year. The type of separator shown in Fig. 10 collects dirt more rapidly than the other form. Contemplated improvements are under way for obviating these difficulties.

99 Gas leaves the furnace top at a temperature of about 550 deg. fahr. In summer it enters the fans at about 77 deg. and leaves the fans at about 60 deg. fahr. The water used in the tower amounts to about 75 gal. per 1000 cu. ft. of gas. The quantity of waste water used in the fan washers is not accurately known.

100 At each fan there are eight nozzles which discharge water into the fan through the upper periphery, and four nozzles which discharge it into the gas inlet openings of the fan. The quantity of water used in the fans, especially at the gas inlet, greatly affects the power required to drive them, which increases with the amount of water used. Each fan at washers Nos. 1 and 2 requires about 45 h.p., while about 60 h.p. is required by each fan at washers Nos. 3 to 6. The operation of about one-half of the fan washers is required under present load

conditions. Hence allowing for losses in motors, about five per cent of the delivered horsepower at the engines is required for driving the fan washers.

101 The cleaning of the gas at washers Nos. 1 and 2 is less complete than that at washers Nos. 3 to 6. At the two former the dust content in second-washed gas as delivered averages about 0.035 grains per cu. ft.

102 At gas washers Nos. 3 and 4 the dust content in the gas is about as follows:

Gas	Cooled	First-Washed	Second-Washed
Average grains per cu. ft.	0.328	0.061	0.022
Maximum grains per cu. ft.	0.980	0.100	0.100
Minimum grains per cu. ft.	0.0044	0.0044	0.0044

103 The gas supplied through the 30-in. main to power house No. 1, therefore, contains more dirt and moisture than that delivered from washers Nos. 3 to 6, in consequence of which there is more trouble with dirt at the power house than at the blowing-engine houses. Also it may be noted that the long 8-ft. gas headers at the blowing-engine houses are of probable value in separating the moisture from the gas.

LUBRICATION

104 As previously noted, each motor cylinder is supplied with cylinder oil by six pumps of the screw plunger type. The pumps are arranged in two batteries, one for each end of the cylinder, each comprising three plungers driven by a combination cam, lever, ratchet, and worm gearing, common to the three plungers of the battery. During each compression stroke of the motor piston the three oil pump plungers are depressed through a small distance into the oil pump cylinders. In this way three small equal quantities of oil are forced into the end of the motor cylinder during the corresponding compression stroke of the motor piston, one quantity entering at the top and the others on either side near the bottom of the motor cylinder, at points about midway between the cylinder head and the exhaust ports. The oil pump discharge connections are filled with oil in order to exclude any possibility of the presence of air. The resulting lubrication is thorough, effective and satisfactory. The oil used is known under the trade name of Electric Gas Engine Oil. The flash test is about 450 deg. fahr. and the oil fires at about 550 deg. fahr. The author believes that the long piston of the two-stroke cycle engine is especially conducive to satisfactory cylinder lubrication. The cylin-

der oil used by each blowing engine amounts to about 5.25 gal. every 24 hours.

105 Engine oil known under the trade name of Dynamo Oil is supplied at the necessary points by means of an oil purification and distributing system already described. This oil circulates again and again through the bearings, and each day a sufficient quantity of filtered oil is taken from the system and used for lubricating the piston rods and the gas and air pump cylinders. The quantity of engine oil used by each blowing engine, including oil actually consumed by the air and gas pump cylinders and motor piston rods, plus the daily waste due to leakage, evaporation, etc., in the purification plant, amounts to about 3.7 gal. in 24 hours.

106 In addition to the above there is required for the blowing cylinder about 0.6 gal. of air-cylinder oil, and for small pin bearings, etc., about 1.25 lb. of No. 2 cup grease per 24 hours. The delivered horsepower of each blowing engine varies from 1000 to 1200.

107 The small pipes for delivering oil to the motor cylinder are screw-threaded into the walls of the cylinder, and project radially through the water jacket, passing out through stuffing boxes in the jacket wall. The steel pipe formerly used corroded rapidly, allowing jacket water to enter the motor cylinder during operation. The substitution of brass pipe eliminated this trouble.

108 It was found that dirt accumulated in the two nipples where the oil enters the motor cylinders at each end near the bottom of the cylinder, and gradually baked with the oil, plugging the connection. An appendix consisting of a pipe tee and cock was provided, into which the dirt settled to be blown out at leisure.

IGNITION

109 The detailed construction of the igniter plugs is indicated in Fig. 24. The bronze bushing forming the spherical seat for the movable steel electrode is a driving fit in the cast-iron body of the plug. The cylindrical head of the stationary electrode seats on an asbestos gasket or washer carried by the porcelain insulating plug which is formed as a conical frustrum seated in a cavity in the cast-iron plug on a bedding of litharge and glycerine. Litharge also assists in maintaining tightness between the cast-iron plug and the bronze bushing. This construction is very satisfactory in every way.

110 Using magneto or similar low voltage current, there is little burning of the points, and the life of both electrodes is about one

year. The bronze bushing lasts about six months, this material being the most satisfactory thus far used. The upkeep of the magnetos is relatively expensive, and a ten-volt direct-current system is being substituted.

111 Dirty plugs are caused by slipping furnaces and wet gas containing dirt which fouls and bakes at the terminals. The plugs require cleaning on an average of once to twice per month. The spherical seat requires regrinding once in two months, and the plug must be retubed one in six months.

112 Premature combustion is due to high hydrogen content in the gas, sharp edges or corners of metal exposed to the flame, dirt, and improper piston packing. Back-fires are due to prematures during the period of inlet opening, or to leaking inlet valves under usual conditions. The plant under discussion has had but little of any such trouble. Miss-fires are due to wet gas, faulty plugs or magnetos and weak mixtures.

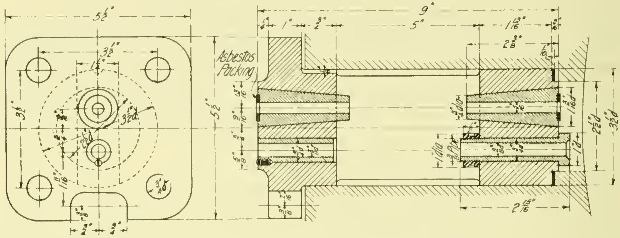


Fig. 24 Details of Igniter Plug

113 An indicator diagram showing premature ignition is shown in Fig. 25. The maximum pressure indicated in this instance was 385 lb. gage per sq. in.

114 With the type of ignition gear in use there is an interval between the release of the magneto lever and the opening of the igniter terminals. There is also an appreciable time required to complete combustion. This time element being approximately constant, correct ignition requires that the timing of the release shall vary to some extent with the speed of rotation. The ignition gear may then be linked to the speed-adjusting device in such manner as automatically to maintain proper timing of the ignition at all speeds.

GOVERNING

115 When designing the adjustable speed-governing apparatus for the blowing engines it was desired to ascertain these quantitative relations, relative to ignition and speed of rotation, and the results of the investigations that were conducted are given in Appendix No. 1.

116 As far as the author has been able to learn, the method of speed regulation as furnished by the makers, consisted in allowing the gas in the pump discharge pipe to flow through adjustable leakage valves, under control of the governor, back into the suction connection or gas main. For the blowing engines as designed, this bypassing could occur only during the suction stroke of the gas pump; hence only that portion of gas which was contained in the discharge duct or passage between pump and inlet valve was subject to this control, the result being that after the pressure in the duct discharged through the bypass valve, no further bypassing occurred, the remainder of the gas from the pump passing on into the motor cylinder whether required or not. The blowing engines could not be governed in this manner.

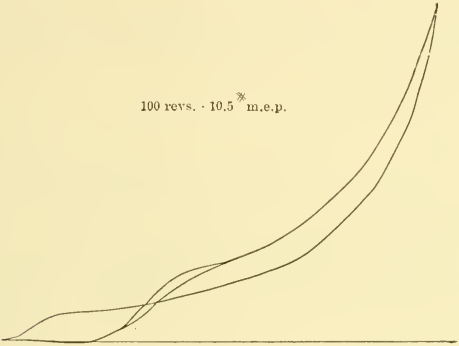


Fig. 25 Indicator Diagram of Premature Combustion

117 As previously noted, at the power house a system of throttle regulation was early applied; and at the blowing engines, governors and valve gears have been applied which allow bypassing to occur during both suction and discharge strokes of the pump. Speed regulation at light load is rather difficult and unsatisfactory on account of miss-fires and other variations in the mean effective pressure, due

to weak and variable mixtures under this condition. Fig. 26 shows the relation between bypass-valve opening and mean effective pressure, for the speed regulating apparatus now in use at the blowing engines. The character of the curve, however, varies considerably with the quality and pressure of the gas.

CYLINDERS, PISTONS, RODS, VALVES, ETC.

118 The average life of a motor cylinder is about four or five years, during which time the wear as measured on a diameter is about three-eighths inches. The cylinder is then bored out and bushed. There are practically no cylinder failures from any cause other than wear.

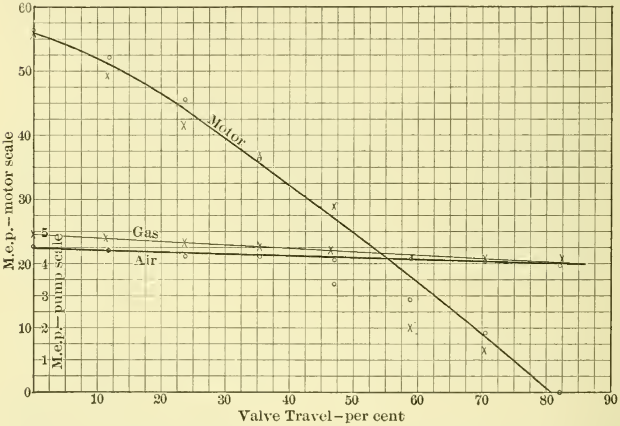


Fig. 26 Calibration of Bypass Valves

119 Exhaust ports at power house No. 1 become clogged with flue dirt and require cleaning after about three months of operation. Exhaust ports at the blowing-engine houses do not foul at all. The difference is probably due to the cleaner gas at the blowing-engine houses, and possibly in some degree to the precipitation of moisture and dirt in the 96-in. headers.

120 Cylinder relief valves require cleaning about once a month. Jackets of cylinders and heads are cleaned about once a year.

121 Cylinders and pistons are inspected only when conditions indicate. Their wear is measured and recorded at the same time. A test for tightness consists in placing the crank on the dead point and subjecting one end of the cylinder to air or exhaust pressure, the plugs being removed from the opposite head to indicate leakage, if any, through the piston. Details of a 38½-in. cylinder are shown in Fig 17.

122 The 38½-in. pistons have a life of from three to five years. There are but few piston failures due to any cause other than wear. A few have occurred which have been due to the water connections falling down inside the piston and wearing a hole through the bottom. When a piston has worn, say $\frac{5}{16}$ in. at the bottom, it is turned over and used in a standard cylinder. There are at present two standard diameters, 38½ in. for new cylinders and 37½ in. for bushed cylinders.

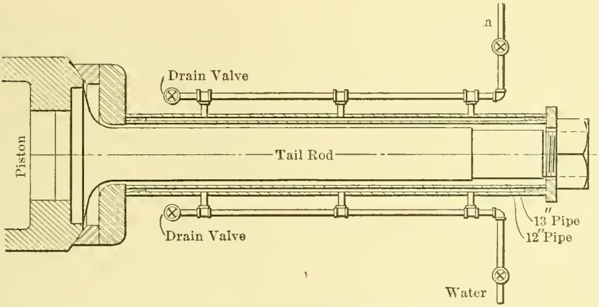


Fig. 27 Device for Stripping Tail Rods

123 The large piston nuts, when dismantling a piston, are heated, removed, cleaned up in the lathe and used again. About half of the small piston nuts have to be split off, the rest being utilized again. There is considerable corrosion around the studs and nuts, and at the joint between rod and piston, thus forming what may be called a rust joint. The tail rods are removed from the piston either by means of the special device shown in Fig. 27 or by means of screw jacks and rams. When using the former, the concentric pipes are first cooled with water and the nut at the end of the tail rod set up; steam is then admitted between the pipes at atmospheric pressure to lengthen the pipes. This cycle is repeated until the rod is free from the piston.

When it becomes necessary to remove the piston rod, the piston is broken away either with dynamite or under the drop hammer.

124 The wear of piston rods occurs principally at the end of the stroke and amounts to about a quarter of an inch on the diameter in three years. It is then turned and will suffice for two or three years more.

125 The average life of the motor cylinder heads is not well established, but it may be set at three years or more. A few of the original heads at the blowing engines are still in service. Failures of these occur principally at the junction of the jacket wall and the main flange on each side of the inlet valve chamber, but this trouble has been substantially eliminated by employing proper fillets. Some heads have developed cracks through the inner wall; two or three have had the inner walls blown entirely away, but this was found due to faulty castings.

126 The inlet valves last about three years before turning and about the same time after they are turned down. They do not require grinding-in except when new. Stems are broken occasionally near the top yoke. Little cleaning of the inlet valve or the ports is necessary.

127 Gas pump cylinders and heads require cleaning every six to eight months on account of dirt getting into the clearance near the bottom. By feeding a little kerosene through the pump valves cleaning is avoided.

128 Cylinder heads are packed principally with $\frac{1}{16}$-in. woven wire insertion asbestos sheet. Piston joints are made up either with $\frac{1}{32}$-in. wetted asbestos paper, or with a paste of litharge and glycerine, or with another form of packing known under the trade name of "900." All give satisfactory results.

129 The life of the $1\frac{7}{16}$-in. snap piston rings is about two years. The openings are securely dowelled in place near the bottom of the cylinder, being thus effectively closed by the piston which is always in contact with the bottom of the cylinder.

130 The piston rods are packed with four cast-iron rings of the Walker type in a casing exterior to the head. Packings are overhauled about every six months to renew broken springs and rings. Casings are trued up at the time of overhauling the piston once in two or three years.

131 The swinging connections for the piston water supply require to be packed about twice a year. The life of the brass goose necks is about two years.

132 Rod connections require keying up on the left side once a year and on the right side once in two months. The main bearings have required no adjustments.

133 The life of the inlet cams is about six years. Wear of the steel gears of the layshaft occurs on four teeth at the end of four or five years; the gears are then shifted on the shaft so that unworn teeth are in action during the inlet valve opening.

134 The inlet valves are operated through heavy push rods driven by cams and rollers. High inertia stresses are thus developed at the higher engine speeds. With present inlet valve springs which operate under a compression of 2500 to 3500 lb. at the blowing engines, the roller leaves contact with the cam at about 65 to 70 r. p.m. Many of the original push rods have been broken by the resulting inertia stresses and new and stronger rods have been made.

135 As previously stated the shaft of the 2000-h.p. engine is of the built-up type and it has been the cause of no trouble whatever. There have been, however, several shaft breakages at the 1000-h.p. engines which have shafts forged in one piece and operate at 100 r.p.m. The author has made no investigation relative to the stresses in these shafts, but believes that their life would have been longer had they been of the built-up type and of present diameters.

136 At the 1000-h.p. engines there has also been trouble with certain brackets and fastenings due to inertia stresses set up by the inlet gear. The governor being driven from the layshaft, considerable wear is imposed on the mechanism due to reversal of the torque at the layshaft as the point of each cam passes under the roller. Some trouble from prematures at the 1000-h.p. engines was experienced, due to the indicator holes through the flange of the cylinder head. Water cooled indicator connections were substituted.

OPERATING COSTS

137 The fuel consumption at the blowing engines amounts to about 18,500 B.t.u. per i.h.p. hour at the blowing cylinder, equivalent to 162,000,000 B.t.u. per h.p. year of 8760 hours. This is equivalent to 5.79 long tons of steam coal which has a heating value of 28,000,000 B.t.u. per ton. Assuming the price of such coal to be $2 per ton, the fuel cost becomes $11.58 per delivered h.p. year of 8760 hours.

138 Other operating costs at blowing-engine house No. 2 for the year 1907 were as follows. A continuous output of 6000 h.p. at the blowing cylinders was assumed, which is as nearly correct as possible, and on this basis the various costs were itemized.

OPERATING COSTS AT BLOWING-ENGINE HOUSE NO. 2 - 1907

Item	Cost per d.h.p. year
Producing labor	$4.504
Labor to repairs and maintenance	0.320
Material to repairs and maintenance	1.152
General	3.962
Total operating cost	$9.94

The total cost of fuel and operation under the conditions assumed is therefore $21.52 per h.p. year of 8760 hours.

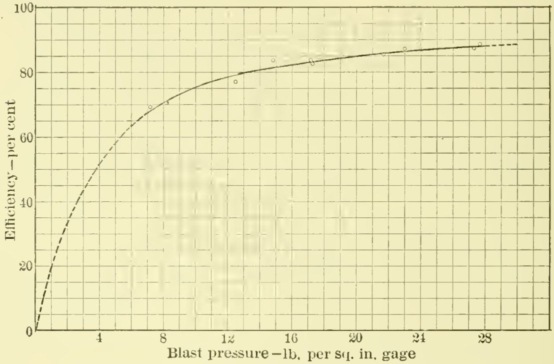


Fig. 28 Gross Mechanical Efficiency Curve

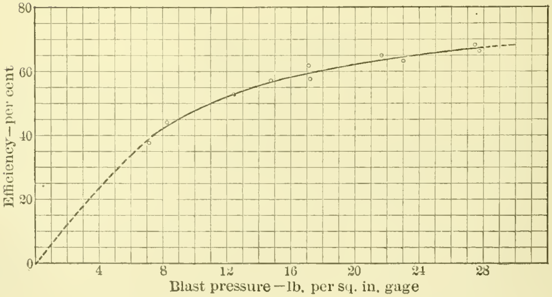


Fig. 29 Net Mechanical Efficiency Curve

OBSERVED QUANTITATIVE RESULTS

139 Some material pertaining to this subject has already been indicated under the heading of General Notes Relating to Operation. A series of efficiency trials, data upon which are tabulated in Appendix No. 3, was run upon one of the blowing engines from which deductions have been made upon the performance of the engine under different conditions of operation.

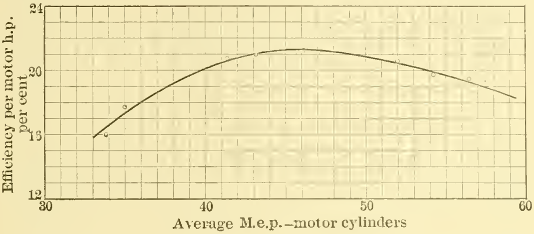


FIG. 30 HEAT TRANSFORMING EFFICIENCY OF MOTOR CYLINDER

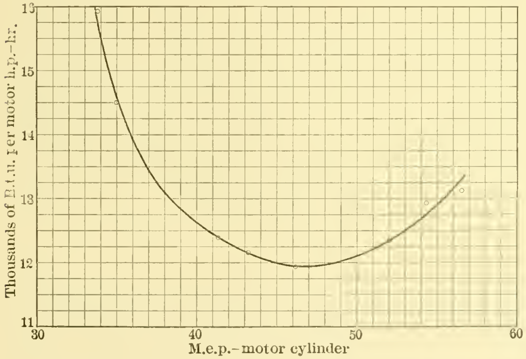


FIG. 31 HEAT CONSUMED PER MOTOR H.P-HOUR

140 The speed regulation during these trials was by throttle and bypass alternately, at least one trial being made under each condition of governing at various blast pressures. In the tabulation, these trials are grouped in pairs, the several blast pressures intended being respectively 5, 10, 15, 20 and 25 lb. per sq. in. nominal gage pressure. It was expected that the bypass method of regulation

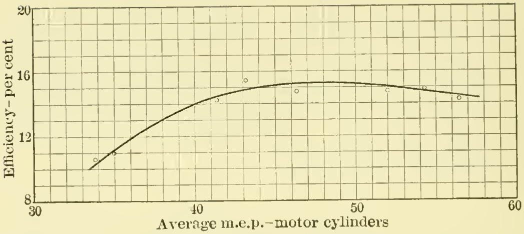


Fig. 32 Combined Heat Transforming Efficiency of Motor and Pump Cylinders

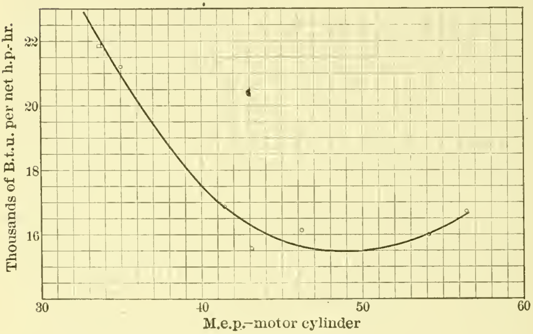


Fig. 33 Heat Consumed per net i.h.p-hour

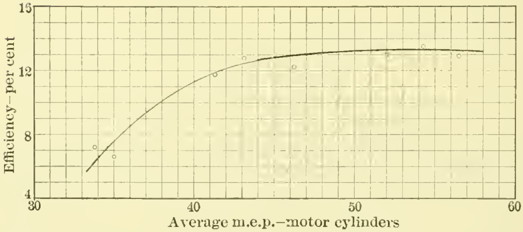


Fig. 34 Combined Heat Transforming Efficiency of Motor Pump and Blowing Cylinders

would show an advantage due to reduced pump work, etc., but such assumption does not seem to be proven, the blast horsepower efficiencies showing substantially the same figure under corresponding load conditions.

141 Fig. 28 represents the gross mechanical efficiency of the mechanism plotted against the blast pressure. It is the ratio of the sum of pump and compressor horsepowers, to the total indicated motor horsepower, and is a measure of the degradation due alone to the mechanical friction of the mechanism. Fig. 29 represents the net mechanical efficiency of the engine, or the ratio of useful work in the blowing cylinder to total indicated work in the motor cylinders, and is a measure of the loss due to the sum of pump work and mechanical friction. A third figure, which might be termed the "real" mechanical efficiency, would be the ratio of work delivered at the blowing cylinder, to the difference between motor work and pump work; or the ratio of delivered indicated horsepower, to net indicated motor horsepower.

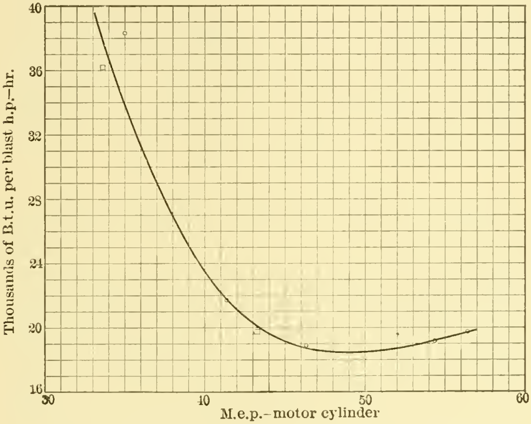


FIG. 35 HEAT CONSUMED PER BLAST H.P.-HOUR

142 The expression net i.h.p. occurring in the tabulated material from the various engine trials is herewith defined as the difference between the total indicated horsepower of the motor cylinders, and the total indicated horsepower of the pumps. Having in mind the

above definition, the curves relating to heat-transforming efficiency, and heat consumption, indicated in Figs. 30 to 35 are self-explanatory.

143 Figs. 36 and 37 are measures of the degradation due to pump work. The curves would have been modified in some degree, had the gas supply pipe and venturi meter been of larger dimensions.

144 Figs. 38 and 39 show the losses due to friction of the mechanism. Figs. 40 and 41 indicate the losses occurring due to incomplete combustion in the motor cylinders under the various load conditions. As will be noted the minimum loss due to this cause is about 30 per cent of the total heat supplied to the engine and accounts for the low conversion efficiency of less than 15 per cent shown by these engines.

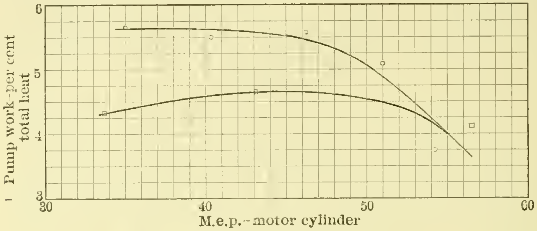


Fig. 36 Pump Work—per cent

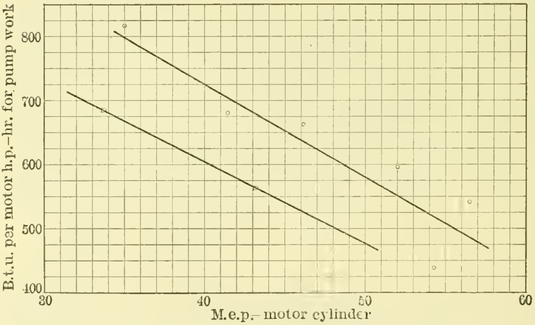


Fig. 37 Pump Work—B.t.u. per Motor h.p.-hour

145 The diagrams of jacket losses shown in Figs. 42 and 43 apparently indicate that losses due to this cause are somewhat erratic

in magnitude. In Fig. 43 an attempt was made to modify these discrepancies by introducing a speed factor, with indifferent success. The jacket loss here shown is believed to be considerably less than is usual with engines of the four-stroke cycle type.

146 Figs. 44 and 45 represent the sensible heat in the exhaust or the balance by difference.

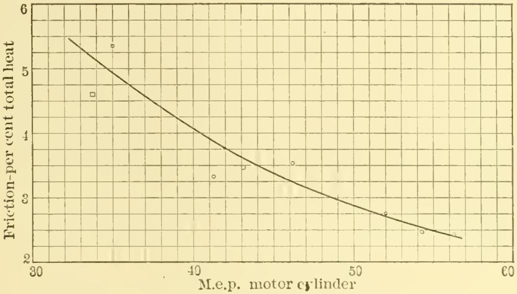


Fig. 38 Friction Loss—per cent of Total Heat

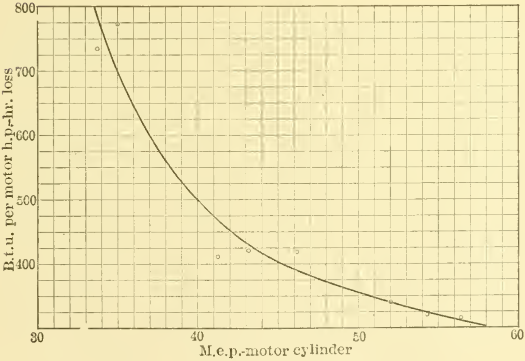


Fig. 39 Friction Loss—B.t.u. per Motor h.p.-hour

147 Fig. 46 is a chart of the various horsepowers plotted against the average blast pressure and Fig. 47 is a diagram of the corresponding percentages based on the motor indicated horsepower and referred to the same abscissae. In Fig. 46 the respective straight line locii of

the motor horsepower and pump horsepower were produced in broken line to intersect the zero axis. The corresponding intercepts show the probable respective values of these quantities at zero blast-pressure. The difference between these two values will then be the probable friction under conditions of zero blast-pressure. From these assumed probable values, corresponding figures were calculated to apply to the percentage chart of Fig. 47, and the respective percentage curves were produced, as shown in broken line, to meet these values.

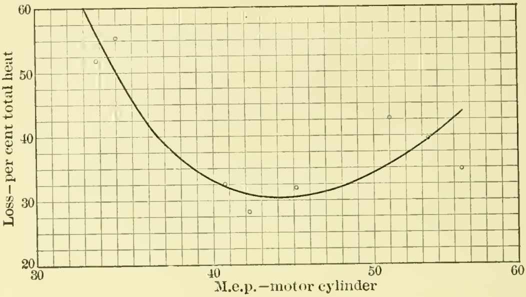


Fig. 40 Incomplete Combustion—per cent of Total Heat

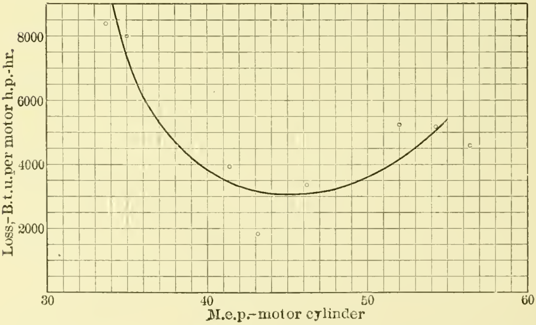


Fig. 41 Incomplete Combustion—B.t.u. per Motor h.p.-hour

148 It will be observed that the horsepower of friction at constant speed varies in considerable degree, and inversely with the torque.

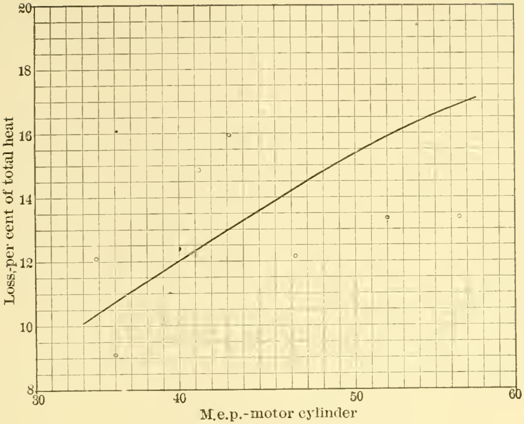


FIG. 42 JACKET LOSS—PER CENT OF TOTAL HEAT

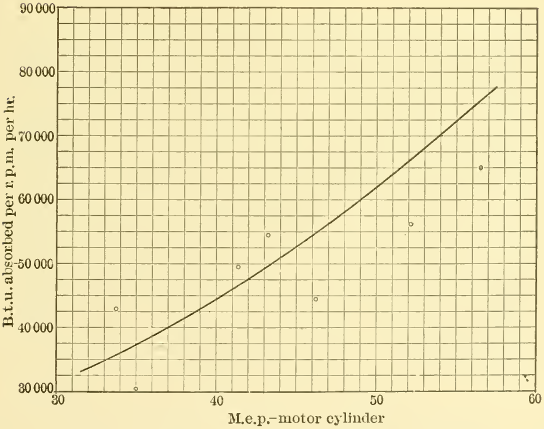


FIG. 43 JACKET LOSS—B.T.U. PER R.P.M. PER HOUR

This may be explained in whole or in part, when it is remembered that the pressure at the bearing is a differential between that due to the inertia of the reciprocating parts and that due to the pressure in the motor cylinder, the inertia pressure being in excess. The bearing pressures at the dead points are therefore reduced by the pressures of compression and explosion.

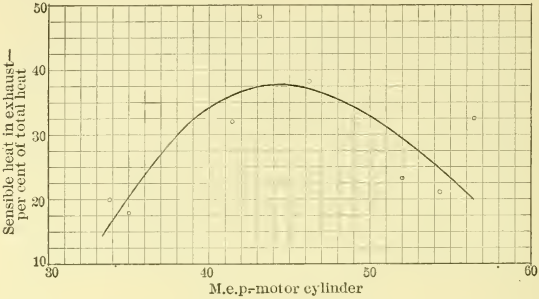


Fig. 44 Sensible Heat in Exhaust—per cent of Total Heat

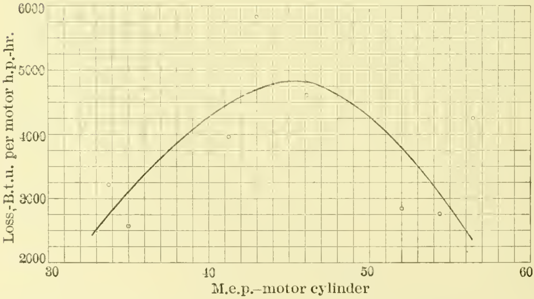


Fig. 45 Sensible Heat in Exhaust—B.t.u. per Motor h. p.-hour

149 Figs. 48 and 49 are efficiency and heat consumption curves obtained from tests of the 1000-h.p. engines.

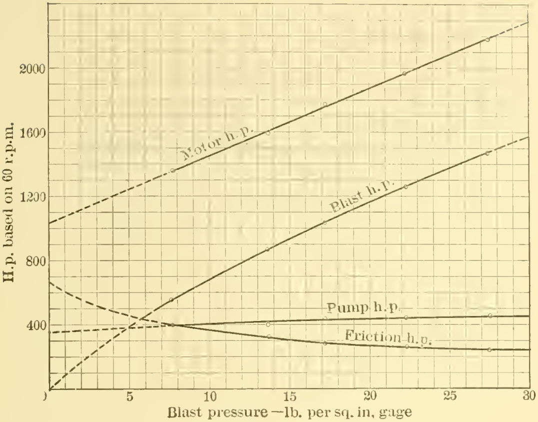


FIG. 46 CURVES OF H.P. AND BLAST PRESSURE

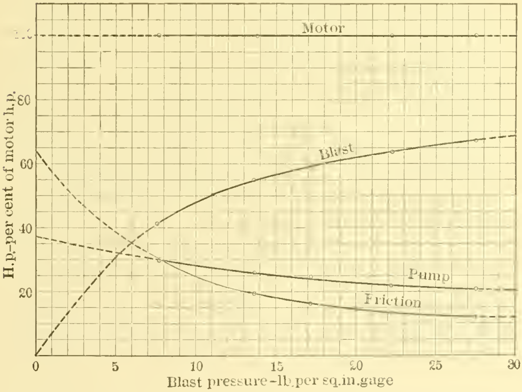


FIG. 47 CURVES OF $\frac{\text{H.P.}}{\text{MOTOR H.P.}}$ AND BLAST PRESSURE

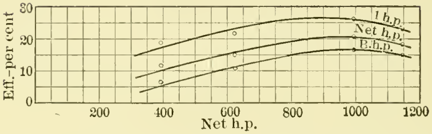


FIG. 48 CURVES OF EFFICIENCY FOR 1000-H.P. ENGINES

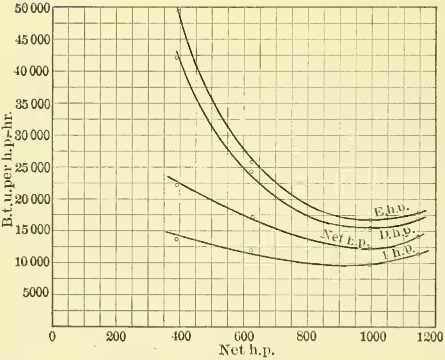


FIG. 49 CURVES OF HEAT CONSUMPTION FOR 1000-H.P. ENGINES

APPENDIX NO. 1

INVESTIGATION TO DETERMINE RELATION BETWEEN POINT OF IGNITION AND SPEED OF ROTATION

150 In this investigation an engine indicator was utilized, the drum motion of the same being derived from the gas pump crosshead. A cord attached to the pencil lever of the indicator was connected first to the magneto lever, and

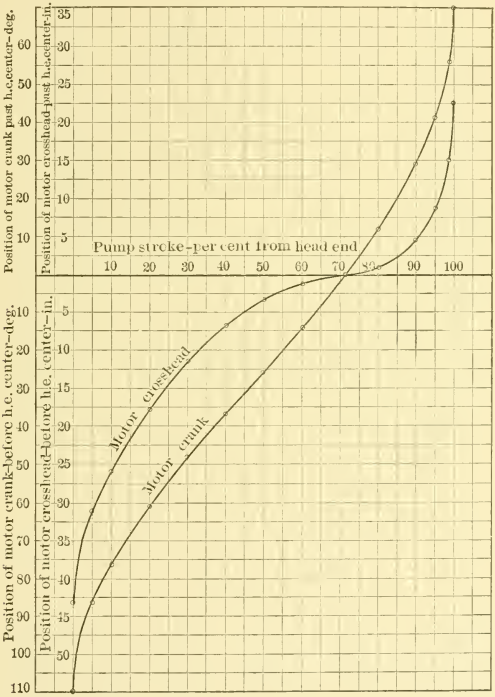


Fig. 50 Relative Positions of Motor Crank and Crosshead for any Position of Pump Crosshead

second to a crank arm on the igniter stem. In this manner the timing of the magneto release, and of the opening of the igniter terminals, both relative to the motion of the gas pump crosshead, were obtained. This investigation was conducted by E. E. Kiger and the results are shown in the form of curves in Figs. 50 to 54 inclusive.

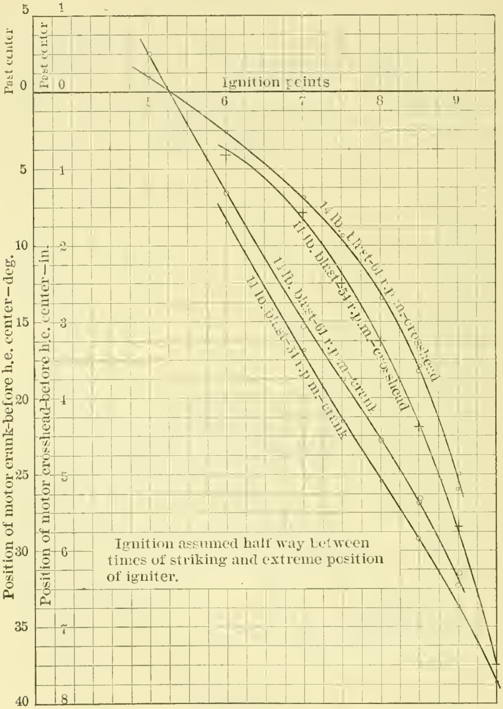


Fig. 51 Positions of Motor Crank and Crosshead for Various Ignition Points when Igniter Opens

151 Following is the explanation of the curves as taken from Mr. Kiger's report.

152 "Curves of Fig. 50 are diagrams of the relative positions of motor crank and motor crosshead to the pump stroke or crosshead, and were drawn by laying out the various positions from the relative crank angles of the engine.

153 "These diagrams were used to locate ignition points relative to motor crank and crosshead after having determined them by experiment relative to the pump crosshead.

154 "Curves on sheet Fig. 51—Diagrams were taken on an indicator pulled from the pump crosshead, the pencil being attached by cord to the igniter. The point taken for ignition is one that is half way between the point of striking the igniter and the extreme position of the igniter. Motor cards were taken together with the ignition cards at different points of ignition from 5 to 9 on the arbitrary index scale of the engine. A series of cards was taken at two speeds, 54 and 61 r.p.m. Enough gas was used at all ignitions to produce good motor cards by regulating the opposite side of the engine. Using curves of Fig. 50, these points were transferred from pump base to motor base as shown on Fig. 51.

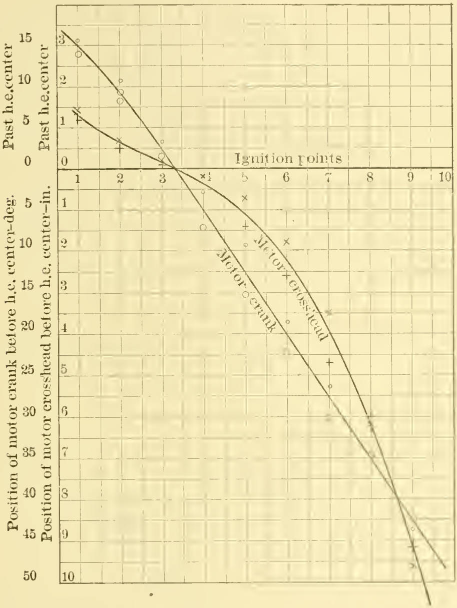


FIG. 52 POSITIONS OF MOTOR CRANK AND CROSSHEAD AT RELEASE OF MAGNETO LEVER FOR VARIOUS IGNITION POINTS

155 "Curves of Fig. 52—Location of motor crank and crosshead is shown at release of magneto lever for the various ignition points on the arbitrary scale. Curves were obtained in similar manner to those on Fig. 51, except that the cord was attached to the release lever of the magneto, instead of to the igniter.

156 "Curves on Fig. 53—While Fig. 51 shows positions for two speeds, Fig. 53 shows positions for various speeds, under both normal and checked condi-

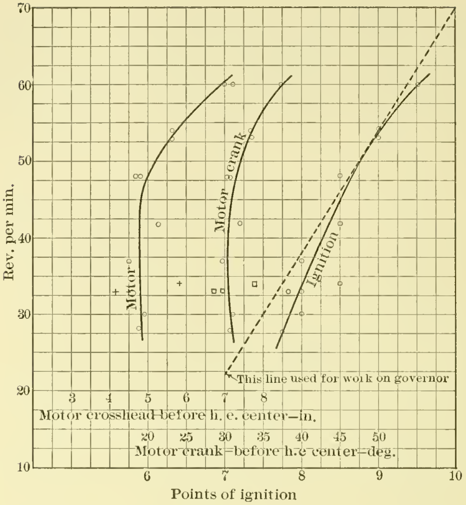


FIG. 53 POSITIONS OF MOTOR CRANK AND CROSSHEAD AND IGNITION POINTS FOR GOOD CARDS AT AVERAGE BLAST AND CHECK CONDITION FOR VARIOUS SPEEDS

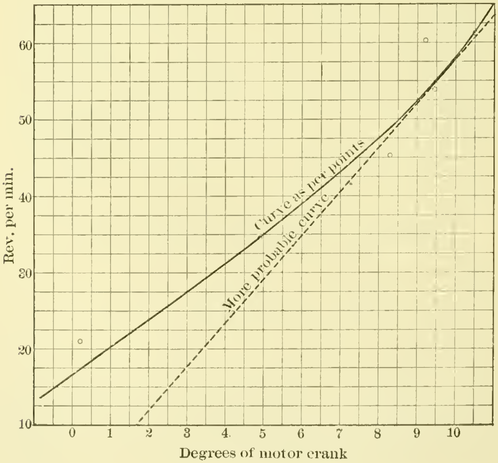


FIG. 54 LAG BETWEEN LEVER RELEASE AND IGNITER OPENING

tions of the furnace. Engine was regulated to give good cards at all speeds. Read by tracing on horizontal from left to right, when intersecting a curve, read down to obtain correct abscissa. A straight line, shown dotted, was used for governor work.

157 "Curves on Fig. 54—Curve as per points was made by combining 52 and 53, giving the lag angle of crank of motor between release of magneto lever and ignition. No points were obtained at low speeds, but at zero speed there would be zero lag angle, therefore the more probable curve is as shown dotted."

158 The motion of the pump was used because of its greater rapidity during the ignition period, thus securing greater accuracy of observation than if the direct motion of the motor crosshead had been utilized. Fig. 53 shows that the actual opening of the igniter circuit occurs under lead angles varying from 30.5 deg. at 30 r.p.m to 37.5 deg. at 60 r.p.m. in order to produce proper timing of the combustion as determined from simultaneous indicator diagrams of the work in the motor cylinder. The corresponding timing of the release of the magneto lever is seen to vary from about 36 deg. at 30 r.p.m. to 49 deg. at 60 r.p.m. The time at which combustion was complete, as determined from the inspection of simultaneous work diagrams in the motor cylinder, was maintained constant, as nearly as could be estimated, at about 10 deg. past the motor crank center.

APPENDIX NO. 2

DIAGRAM SHOWING LOSSES DUE TO AIR AND GAS PUMPS

159 Fig. 56 shows crank circle diagram of the various events for the motor cylinder, the timing of the various events such as opening and closing the inlet and exhaust valves, etc., being indicated in degrees referred to the motor crank dead points.

160 Figs. 55, 57 and 58 are pressure diagrams taken at the various pump cylinders and connections as noted thereon. Fig. 57 is an average of head and crank diagrams referred to a pump-piston motion base line. Figs. 55 and 58 are similar diagrams referred to the motion of the motor piston. The method of governing at the time these diagrams were taken was throttling. From the diagrams the pressure losses through the various parts of the apparatus supplying air and gas may be deduced. This pump work, amounting to 20 per cent or more of the indicated horsepower, is one of the limiting factors preventing the attainment of the best economy from the engines as constructed.

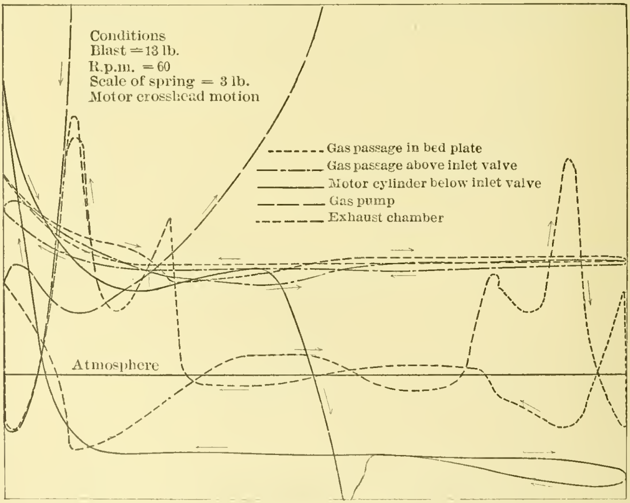


Fig. 55 Average Diagrams from Gas Pump (Motor Base)

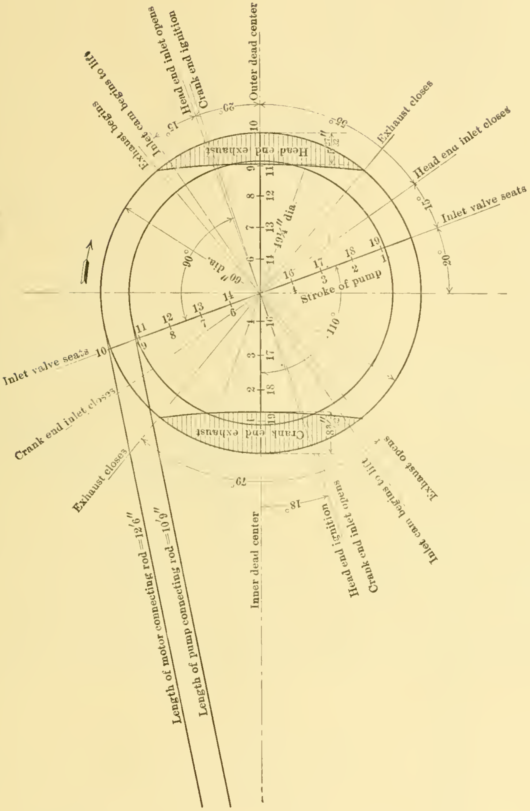


FIG. 56 CRANK CIRCLE DIAGRAM OF MOTOR

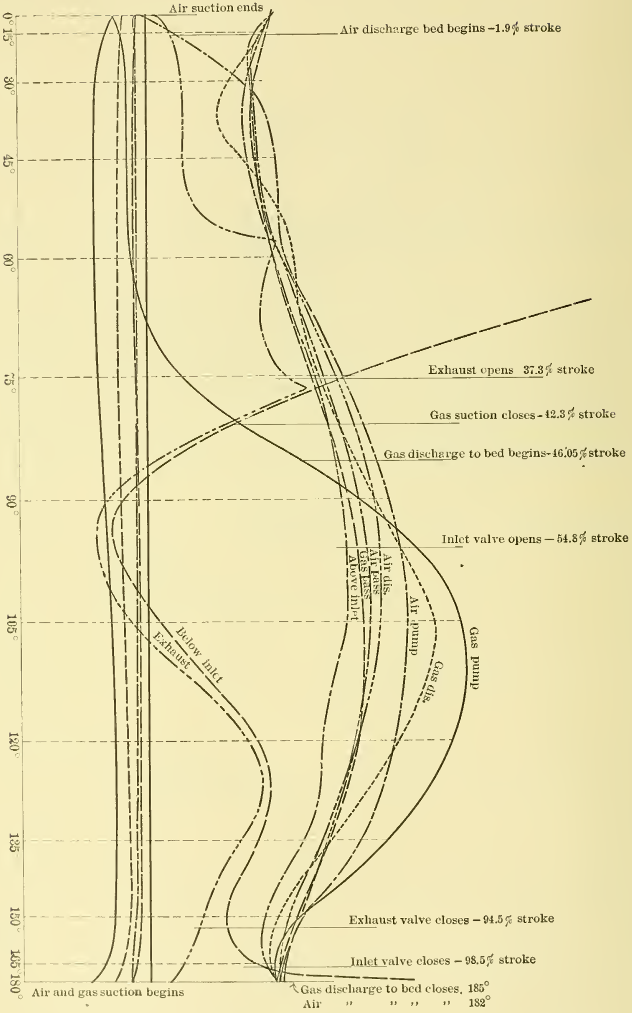


Fig. 57 Average Diagrams from Gas and Air Pumps (Pump Base)

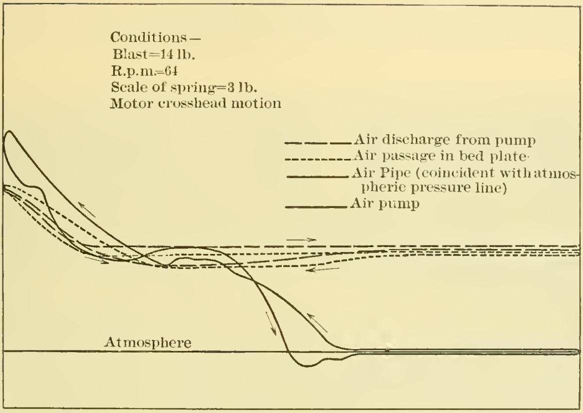


Fig. 58 Average Diagrams from Air Pump (Motor Base)

APPENDIX NO. 3

DATA UPON EFFICIENCY TRIALS OF 2000-H.P. BLOWING ENGINE

161 The following matter is principally the tabulation of data and calculated results from a series of efficiency trials at one of the blowing engines.

162 The measurement of the gas was by means of a 16-in. venturi meter in the gas-supply pipe leading to the pumps. The general arrangement of meter, surge tank and piping are shown in Fig. 59. The meter is a little small for the service, in consequence of which the blast pressure could not be carried beyond 28 lb. gage. The coefficient of the meter was assumed to be unity, and no corrections were made for dirt or moisture in the gas, same not being observed.

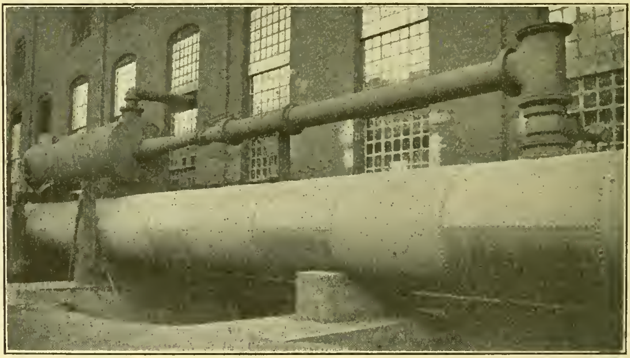


Fig. 59. General Arrangement of Meter and Piping

163 The composition of the gas was obtained by means of an Orsat apparatus, which was equipped with a palladium tube for the determination of hydrogen. A continuous sample was taken and analyzed at the end of the trial; another was taken from each of the exhaust pipes and analyzed after the completion of the run. Correction of the carbon-monoxide in the exhaust gases was made as shown in the correction chart for Orsat apparatus, Fig. 60, plotted from the data of Dennis and Edgar. For determining the calorific power of the gas, the high heating value of the gas, as calculated from the analysis, was used.

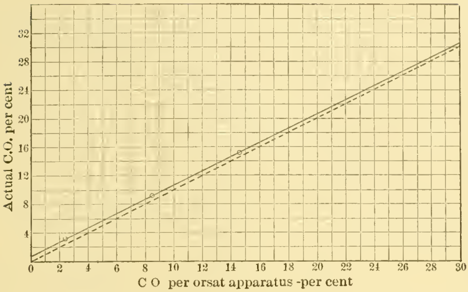


FIG. 60 CORRECTION CHART FOR ORSAT APPARATUS

164 The jacket water was determined by means of two orifices in a thin plate, one inserted in each piston water-supply pipe. The calibration curves of these orifices are shown in Figs. 61 and 62.

165 The calibrations of all instruments used for observing pressures and temperatures were known. The diameters of the various cylinders were not calipered, but the error due to this neglect can not be great.

166 Representative indicator diagrams for various of the tests are shown in Figs. 63 to 67. The various efficiencies and heat consumptions are indicated the form of curves. In the plotting of these curves, tests 31 and 36 were disregarded because of discrepancies in the gas analyses.

167 The dilution coefficient of the exhaust gases includes the scavenging air. The method used for obtaining the coefficient is given below.

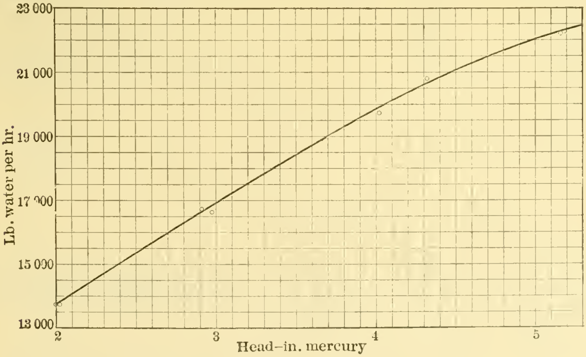


FIG. 61 ORIFICE CALIBRATION CURVES

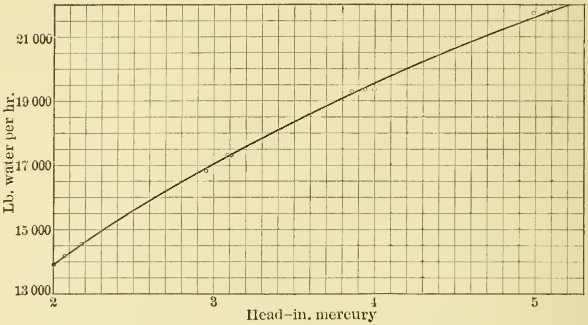


FIG. 62 ORIFICE CALIBRATION CURVES

DILUTION COEFFICIENT OF EXHAUST GASES

Let

N_0 = nitrogen in fuel
N_1 = nitrogen in theoretic air for combustion
N_2 = nitrogen in actual air supplied
N_3 = nitrogen in excess air supplied
N = nitrogen in products of combustion
X = dilution coefficient

$$X = \frac{N_2}{N_1} = \frac{N_2}{N_2 - N_3} = \frac{N_1 + N_3}{N_1} \quad \ldots\ldots [1]$$

168 Equation [1] is true for volume or weight analysis, and if little or no nitrogen exists in the fuel, then $N_1 = N$, and, as is usual,

$$X = \frac{N}{N - N_3} \quad \ldots\ldots [2]$$

$$= \frac{N}{N - \frac{79}{21}(O - CO)} \text{ for volume analysis}$$

$$= \frac{N}{N - \frac{7677}{2323}\left(O - \frac{16}{28} CO\right)} \text{ for weight analysis}$$

169 In the present instance, where the fuel contained appreciable nitrogen, the following methods and notation were used, the volume analysis of the exhaust gases being reduced to equivalent weight analysis:

A = theoretic air required in lb. per min.
O = weight fraction of oxygen in exhaust gases
CO = weight fraction of CO in exhaust gases

N = weight fraction of nitrogen in exhaust gases
N_0 = nitrogen in fuel in lb. per min.
Y = air supplied in lb. per min.
Z = exhaust gases in lb. per min.

$$0.7677\,Y + N_0 = NZ = \text{total nitrogen} \ldots\ldots\ldots\ldots [3]$$

$$Y - A = \frac{Z}{0.2323}\left(O - \frac{16}{28}CO\right) = \text{excess air} \ldots\ldots\ldots\ldots [4]$$

$$Z = \frac{N_0 + 0.7677\,A}{N - 3.305\left(O - \frac{16}{28}CO\right)}$$

$$Y = \frac{NZ - N_0}{0.7677}$$

$$X = \frac{Y}{A}$$

TEST OF NO. 2 GAS ENGINE AT 7.65-LB. BLAST PRESSURE

DATA RELATING TO TESTS

1 Number of test	27	37
2 Date of test, 1909	April 9	April 15
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter	16 in., Area 1.396 sq. ft.	
Throat diameter	$6\frac{1}{4}$ in., Area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	57.92	57.60
9 Gas pressure, in. water	7.37	12.61
10 $P_1 - P_2$, in. water	16.38	22.23
11 Gas temperature, deg. fahr	36.6	47.5
12 Barometer, in. mercury	29.18	29.63
13 Absolute pipe pressure, lb. per sq. in	14.58749	14.99743
14 Absolute throat pressure, lb. per sq. in	13.99642	14.19526
15 Ratio $\frac{P_2}{P_1}$	0.959481	0.9465
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.3380	0.3863

JACKET WATER

Right Side

17 Water used per hr., lb	8100	11,100
18 Temperature inlet, deg. fahr	39	39.5
19 Temperature discharge, deg. fahr	118	150

Left Side

20 Water used per hr., lb	8650	10,700
21 Temperature inlet, deg. fahr	39	39.5
22 Temperature discharge, deg. fahr	168.1	154.4

Fuel Gas Analysis by Volume

23 CO_2, per cent	8.8	12.8
24 O, per cent	0.3	0.1
25 CO, per cent	28.1	26.2
26 H, per cent	1.0	0.7
27 N (by difference), per cent	61.8	60.2
28 Weight per cu. ft., standard conditions, lb	0.0814588	0.0834342
29 Weight per cu. ft., test conditions, lb	0.08016984	0.0826120
30 Heating value per cu. ft., standard conditions, B.t.u	99.291	91.771
31 Heating value per. cu. ft., test conditions, B.t.u	97.7199	90.8666

Exhaust Gas Analysis by Volume

Right Side		
32 CO, per cent	6.5	9.0
33 O, per cent	13.6	11.8
34 CO, per cent	4.0	4.3
35 N (by difference), per cent	75.9	74.9
Left Side		
36 CO, per cent	5.8	8.6
37 O, per cent	13.4	11.8
38 CO, per cent	4.1	4.4
39 N (by difference), per cent	76.7	75.2

Cylinder Pressures and Horsepowers

Number of test	27	37
Date of test, 1909	April 9	April 15

Mean Effective Pressures

Motor		
Right head	21.46	37.40
Crank	28.73	33.26
Left head	47.21	38.03
Crank	42.60	26.40
Air pump		
Right head	4.37	4.13
Crank	4.71	3.73
Left head	5.30	4.48
Crank	4.66	4.06
Gas pump		
Right head	5.88	4.53
Crank	5.74	4.52
Left head	6.19	5.01
Crank	5.95	4.55
Air tub		
Head	6.17	7.08
Crank	6.51	7.29

Horsepowers

Motor		
Right head	204.47	354.37
Crank	273.73	315.15
Left head	449.81	360.34
Crank	405.89	250.15

Air pump		
Right head	35.56	33.42
Crank	38.19	30.08
Left head	43.13	36.26
Crank	37.79	32.74
Gas pump		
Right head	67.43	51.66
Crank	75.69	51.45
Left head	70.99	57.14
Crank	68.10	51.79
Air tub		
Head	245.62	280.29
Crank	256.29	285.41

RESULTS OF TESTS

1 Number of test	27	37
2 Date of test, 1909	April 9	April 15
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	7.1	8.2
5 R.p.m. of engine	57.92	57.60
6 Gas per hr., standard conditions, cu. ft	193,846	222.635
7 Gas per hr., test conditions, cu. ft	196,963	224,851
8 B.t.u. per cu. ft., standard conditions	99.291	91.771
9 B.t.u. per cu. ft., test conditions	97.7199	90.8666
10 Total B.t.u. in gas per hr	19,247,230	20,431,500
11 I.h.p. of motor cylinders	1,333.90	1,280.01
12 I.h.p. of air pumps	154.67	132.50
13 I.h.p. of gas pumps	272.21	212.04
14 I.h.p. of blowing cylinder	501.91	565.70
15 I.h.p. net	907.02	935.47
16 I.h.p. friction	405.11	369.76
17 Gross mechanical efficiency of engine, per cent	69.63	71.28
18 Net efficiency of engine, per cent	37.63	44.19
19 Cu. ft. of gas per i.h.p-hr., standard conditions	145.32	173.93
20 Cu ft. gas per net h.p-hr., standard conditions	213.72	237.99
21 Cu. ft. gas per blast h.p-hr., standard conditions	386.22	393.56
22 B.t.u. per. i.h.p-hr	14,492	15,961
23 B.t.u. per net h.p-hr	21,220	21,841
24 B.t.u. per blast h.p-hr	38,348	36,117
25 Efficiency per i.h.p., per cent	17.64	15.94
26 Efficiency per net h.p., per cent	11.99	11.65
27 Efficiency per blast h.p., per cent	6.64	7.05
28 Dilution coefficient	3.66	2.95
29 Potential heat in exhaust per hr., B.t.u	10,667,950	10,592,600
30 Heat absorbed by jacket water per hr., B.t.u	1,761,670	2,462,630
31 Sensible heat in exhaust, etc. per hr., by difference B.t.u	3,422,750	4,121,030

DISTRIBUTION OF TOTAL HEAT

32 Delivered to the blast, per cent	6.64	7.05
33 Pump work, per cent	5.65	4.29
34 Friction, per cent	5.35	4.60
35 Absorbed by jacket, per cent	9.15	12.05
36 Incomplete combustion, per cent	55.43	51.84
37 Balance by difference, per cent	17.18	20.17

TEST OF NO. 2 GAS ENGINE AT 13.65 LB. BLAST PRESSURE
DATA RELATING TO TESTS

1 Number of test	28	36
2 Date of test, 1909	April 9	April 15
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, area 1.396 sq. ft.	
Throat diameter, in	6¼, area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	58	57.92
9 Gas pressure, in. water	7.81	11.01
10 $P_1 - P_2$, in. water	16.43	24.72
11 Gas temperature, deg. fahr	38	42.5
12 Barometer, in. mercury	29.13	29.62
13 Absolute pipe pressure, lb. per sq. in	14.57882	14.93479
14 Absolute throat pressure, lb. per sq. in	13.98594	14.04277
15 Ratio $\frac{P_2}{P_1}$	0.95933	0.9403
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.3385	0.406

Jacket Water

Right Side

17 Water used per hr., lb	8000	10,900
18 Temperature inlet, deg. fahr	39	39.5
19 Temperature discharge, deg. fahr	180.8	149.7

Left Side

20 Water used per hr., lb	12,950	10,750
21 Temperature inlet, deg. fahr	39	39.5
22 Temperature discharge, deg. fahr	172.8	145.1

Fuel Gas Analysis by Volume

23 CO_2 per cent	8.8	12.6
24 O, per cent	.2	.2
25 CO, per cent	28.4	26.0
26 H, per cent	1.0	1.0
27 N (by difference), per cent	61.6	60.2
28 Weight per cu. ft., standard conditions, lb	0.0814471	0.0831388
29 Weight per cu. ft., test conditions, lb	0.079886	0.0827898
30 Heating value per cu. ft. standard conditions, B.t.u.	100.314	92.13
31 Heating value per cu. ft. test conditions, B.t.u.	98.391	91.7431

Exhaust Gas Analysis by Volume

Right Side

32 CO_2 per cent	8.0	9.0
33 O, per cent	12.5	11.0
34 CO per cent	3.0	5.1
35 N (By difference), per cent	76.5	74.9

Left Side

36 CO_2, per cent	8.0	9.2
37 O, per cent	12.3	11.2
38 CO, per cent	2.8	4.8
39 N (by difference) per cent	76.9	74.8

CYLINDER PRESSURES AND HORSEPOWERS

Number of test	28	36
Date of test, 1909	April 9	April 15

MEAN EFFECTIVE PRESSURES

Motor		
Right head	31.62	40.02
Crank	42.28	37.99
Left head	46.68	44.87
Crank	44.50	33.69
Air pump		
Right head	4.45	4.06
Crank	4.51	3.86
Left head	5.46	4.57
Crank	4.85	4.20
Gas pump		
Right head	5.42	4.62
Crank	5.47	4.60
Left head	6.15	5.26
Crank	5.92	4.72
Air tub		
Head	11.18	9.84
Crank	11.50	10.22

HORSEPOWERS

Motor		
Right head	301.69	381.30
Crank	403.39	361.96
Left head	445.37	427.51
Crank	424.57	320.99
Air pump		
Right head	36.26	33.04
Crank	36.62	31.30
Left head	44.49	37.19
Crank	39.38	34.06
Gas pump		
Right head	62.24	52.98
Crank	62.69	52.65
Left head	70.63	60.32
Crank	67.85	54.02
Air tub		
Head	445.67	391.71
Crank	453.36	402.34

RESULTS OF TESTS

1	Number of test	28	36
2	Date of test, 1909	April 9	April 15
3	Method of regulation	Throttle	Bypass
4	Blast pressure, lb	14.8	12.5
5	R. p. m. of engine	58	57.92
6	Gas per hr., standard conditions, cu. ft.	193,760	234,581
7	Gas per hr., test conditions	197,546	235,570
8	B.t.u. per cu. ft., standard conditions	100.314	92.13
9	B.t.u. per cu. ft., test conditions	98.391	91 7431
10	Total B.t.u. in gas per hr	19,436,800	21,611,970
11	I.h.p. of motor cylinders	1575.02	1491.76
12	I.h.p. of air pumps	156.75	135.59
13	I.h.p. of gas pumps	263.41	219.97

14 I.h.p. of blowing cylinder	899.03	794.05
15 I.h.p. net	1154.86	1136.20
16 I.h.p. friction	255.83	342.15
17 Gross mechanical efficiency of engine, per cent	83.76	77.07
18 Net mechanical efficiency of engine, per cent	57.08	53.23
19 Cu. ft. of gas per i.h.p. hr., standard conditions	123.02	157.25
20 Cu. ft. gas per net h.p., hr., standard conditions	167.78	206.46
21 Cu. ft. gas per blast h.p., hr., standard conditions	215.52	295.42
22 B.t.u. per i.h.p-hr	12,341	14,488
23 B.t.u. per net h.p-hr	16,830	19,021
24 B.t.u. per blast h.p-hr	21,620	27,217
25 Efficiency per i.h.p., per cent	20.62	17.57
26 Efficiency per net h.p.	15.12	13.38
27 Efficiency per blast h.p., per cent	11.77	9.35
28 Dilution coefficient	3.45	4.081
29 Potential heat in exhaust per hr., B.t.u	6,313,100	13,505,700
30 Heat absorbed by jacket water per hr. B.t.u	2,878,390	2,342,880
31 Sensible heat in exhaust, etc. per hr. by difference, B.t.u	6,236,880	1,966,690

Distribution of Total Heat

32 Delivered to the blast, per cent	11.77	9.35
33 Pump work, per cent	5.50	4.19
34 Friction, per cent	3.35	4.03
35 Absorbed by jackets, per cent	14.81	10.84
36 Incomplete combustion, per cent	32.48	62.49
37 Balance by difference, per cent	32.09	9.10

TEST OF NO. 2 GAS ENGINE AT 17.15-LB. BLAST PRESSURE

1 Number of test	29	30
2 Date of test, 1909	April 10	April 10
3 Duration of test, min	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area 1.396 sq. ft.	
Throat diameter, in	6¼, Area 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	61.35	59.75
9 Gas pressure, in. water	9.35	14.51
10 P_1-P_2, in. water	27.33	21.78
11 Gas temperature, deg. fahr	39.6	38
12 Barometer, in. mercury	29.53	29.58
13 Absolute pipe pressure, lb. sq. in	14.83071	15.04146
14 Absolute throat pressure	13.84451	14.25553
15 Ratio $\frac{P_2}{P_1}$	0.933503	0.94775
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.427	0.382

Jacket Water

Right Side

17 Water used per hr., lb	8975	13,050
18 Temperature inlet, deg. fahr	38	40
19 Temperature discharge, deg. fahr	153.4	173.7

Left Side

20 Water used per hr.	14,800	11,950
21 Temperature inlet, deg. fahr	38	40
22 Temperature discharge, deg. fahr	151	167.70

Fuel Gas Analysis by Volume

23 CO_2, per cent	10.4	10.7
24 O, per cent	0.2	0 2
15 CO, per cent	25.7	26 4
26 H, per cent	1.3	0 5
27 N (by difference), per cent	62.4	62 2
28 Weight per cu. ft., standard conditions, lb	0.0819455	0 0826587
29 Weight per cu. ft., test conditions, lb	0.077834	0.0836471
30 Heating value per cu. ft., standard conditions, B.t.u.	92 149	91.759
31 Heating value per cu. ft., test conditions, B.t.u	87.5255	92 8562

Exhaust Gas Analysis by Volume

Right Side		
32 CO_2 per cent	9.1	11.0
33 O, per cent	11.4	10.5
34 CO, per cent	2.1	0.5
35 N (by difference), per cent	77.4	78.0
Left Side		
36 CO_2 per cent	9.1	9.5
37 O, per cent	11.1	11.1
38 CO, per cent	2.0	1 1
39 N (by difference)	77.8	78.3

Cylinder Pressures and Horsepowers

Number of test	29	30
Date of test, 1909	April 10	April 10

Mean Effective Pressures

Motor		
Right head	39.66	44.06
Crank	45.64	44.84
Left head	48.76	41 95
Crank	50.79	41 49
Air pump		
Right head	5.28	4.41
Crank	5.56	4.25
Left head	6.02	4 73
Crank	5.45	4.42
Gas pump		
Right head	5.96	4.57
Crank	5 89	4.82
Left head	6.31	5.07
Crank	6.20	4.76
Air tub		
Head	12 73	12 74
Crank	12.76	12.66

Horsepowers

Motor		
Right head	400.25	433 06
Crank	460.60	440 73
Left head	492.09	412 32
Crank	512.58	407.80
Air pump		
Right head	45.51	37 02
Crank	47.75	35.55
Left head	51.89	39 71
Crank	46.81	36 97

Gas pump		
Right head	72 40	54 07
Crank	71.40	56.91
Left head	76 65	59.98
Crank	75.16	56.20
Air tub		
Head	536.77	523.18
Crank	532.09	514.15

RESULTS OF TESTS

1 Number of test	29	30
2 Date of test, 1909	April 10	April 10
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	17.2	17.1
5 R.p.m. of engine	61.35	59.75
6 Gas per hr., standard conditions, cu. ft	241,853	223,910
7 Gas per hr., test conditions, cu. ft	254,630	221,293
8 B.t.u. per cu. ft., standard conditions	92.149	91.759
9 B.t.u. per cu. ft., test conditions	87.5255	92.8562
10 Total B.t.u. in gas per hr	22,286,500	20,548,400
11 I.h.p. of motor cylinders	1,865.52	1,693.91
12 I. h.p. of air pumps	191.96	149.25
13 I.h.p of gas pumps	295.61	227.16
14 I.h.p. of blowing cylinder	1068.86	1037.33
15 I.h.p. net	1377.95	1317.50
16 I.h.p. friction	309.09	280.17
17 Gross mechanical efficiency of engine, per cent	83.43	84.43
18 Net mechanical efficiency of engine, per cent	57.30	61.24
19 Cu. ft. gas per h.p. hr., standard conditions	129.64	132.20
20 Cu. ft. gas per net h.p. hr., standard conditions	175.52	169.97
21 Cu. ft. gas per blast h.p. hr., standard conditions	226.27	215.88
22 B.t.u. per i.h.p-hr.	11,948	12,131
23 B.t.u. per net h.p-hr	16,174	15,597
24 B.t.u. per blast h.p-hr	20,850	19,809
25 Efficiency per i.h.p., per cent	21.30	20.98
26 Efficiency per net h.p., per cent	15.74	16.32
27 Efficiency per blast h.p., per cent	12.21	12.85
28 Dilution coefficients	3.1	3.149
29 Potential heat in exhaust per hr., B.t.u.	6,243,500	3,048,400
30 Heat absorbed by jacket water per hr	2,715,250	3,282,940
31 Sensible heat in exhaust, etc., per hr. by difference, B.t.u	8,582,500	9,904,330

Distribution of Total Heat

32 Delivered to the blast, per cent	12.21	12.85
33 Pump work, per cent	5.56	4.66
34 Friction, per cent	3.53	3.47
35 Absorbed by jacket, per cent	12.18	15.98
36 Incomplete combustion, per cent.	28.01	14.84
37 Balance of difference, per cent	38.51	48.20

TEST OF NO. 2 GAS ENGINE AT 22.35-LB. BLAST PRESSURE

1 Number of test	32	31
2 Date of test, 1909	April 12	April 12
3 Duration of test, min.	60	60
4 Method of regulation	Throttle	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area, 1.396 sq.ft.	
Throat diameter, in	6½, Area, 0.213 sq.ft.	

7 Number of venturi observations	13	13
8 R.p.m. of engine	51.65	59.72
9 Gas pressure, in water	11.75	12.75
10 P_1-P_2, in. water	38.33	25.51
11 Gas temperature, deg. fahr	60	61
12 Barometer, in mercury	29.43	29.52
13 Absolute pipe pressure, lb. sq. in	14.86824	14.9485
14 Absolute throat pressure, lb. sq. in	13.48510	14.02797
15 Ratio $\frac{P_2}{P_1}$	0.096973	0.93842
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.4968	0.412

JACKET WATER

Right side		
17 Water used per hr., lb	12,600	12,200
18 Temperature inlet, deg. fahr	40.5	40.5
19 Temperature discharge, deg. fahr	178.3	154.3
Left side		
20 Water used per hr., lb	13,100	12,650
21 Temperature inlet, deg. fahr	40.5	40.5
22 Temperature discharge, deg. fahr	172.7	167

FUEL GAS ANALYSIS BY VOLUME

23 CO_2 per cent	12.7	11.3
24 O, per cent	0.2	0.1
25 CO, per cent	26.5	24.1
26 H, per cent	0.7	0.7
27 N (by difference), per cent	59.9	63.8
28 Weight per cu. ft., standard conditions, lb.	0.0834002	0.0827742
29 Weight per cu. ft. test conditions, lb	0.0799028	0.0795783
30 Heating value per cu.ft. standard conditions, B.t.u.	92.794	84.61
31 Heating value per cu. ft. test conditions, B.t.u	88.9072	81.3433

EXHAUST GAS ANALYSIS BY VOLUME

Right Side		
32 CO_2 per cent	11.2	11.7
33 O, per cent	9.8	9.8
34 CO per cent	4.6	2.4*
35 N (by difference), per cent	74.4	76.1
Left Side		
36 CO_2 per cent	11.6	10.2
37 O, per cent	9.6	10.1
38 CO, per cent	4.0	2.6
39 N (By difference)	74.8	77.1

CYLINDER PRESSURES AND HORSEPOWERS

Number of test	32	31
Date of test, 1909	April 12	April 12

MEAN EFFECTIVE PRESSURES

Motor		
Right head	48.89	45.51
Crank	52.16	59.06
Left head	52.70	50.06
Crank	54.31	48.41

*Assumed value.

Air pump		
Right head	5.68	4.39
Crank	5.93	4.20
Left head	6.31	4.90
Crank	5.78	4.52
Gas pump		
Right head	5.82	4.64
Crank	5.80	4.85
Left head	6.21	5.31
Crank	5.99	4.96
Air tub		
Head	15.40	14.78
Crank	16.23	15.47

HORSEPOWERS

Motor		
Right head	495.81	447.09
Crank	528.98	481.96
Left head	534.45	491.79
Crank	550.78	475.58
Air pump		
Right head	49.20	36.84
Crank	51.18	35.12
Left head	54.66	41.11
Crank	49.89	37.79
Gas pump		
Right head	71.04	54.87
Crank	70.66	57.23
Left head	75.80	62.79
Crank	72.97	58.53
Air tub		
Head	652.53	606.65
Crank	680.09	627.95

RESULTS OF TESTS

1 Number of test	32	31
2 Date of test, 1909	April 12	April 12
3 Method of regulation	Throttle	Bypass
4 Blast pressure, lb	23.0	21.7
5 R.p.m. of engine	61.65	59.72
6 Gas per hr., standard conditions, cu. ft	280,485	234,521
7 Gas per hr., test conditions, cu. ft	292,762	243,937
8 B.t.u. per cu. ft., standard conditions	92.794	84.61
9 B.t.u. per cu. ft., test conditions	88.9027	81.3433
10 Total B.t.u. in gas per hr	26,027,300	19,842,850
11 I.h.p. of motor cylinders	2110.02	1896.42
12 I.h.p. of air pumps	204.93	150.86
13 I.h.p. of gas pumps	290.47	233.42
14 I.h.p. of blowing cylinder	1332.62	1234.60
15 I.h.p. net	1461.62	1512.14
16 I.h.p. friction	282.00	277.54
17 Gross mechanical efficiency of engine, per cent	86.64	85.37
18 Net mechanical efficiency of engine, per cent	63.16	65.10
19 Cu. ft. gas per i.h.p. hr., standard conditions	132.93	123.67
20 Cu. ft. gas per net h.p. hr., standard conditions	154.57	155.09
21 Cu. ft. gas per h.p. hr., standard conditions	210.48	189.96
22 B.t.u. per i.h.p-hr	12,335	10,464
23 B.t.u. per net. h.p-hr	14,343	13,122
24 B.t.u. per blast h.p-hr	19,531	16,072

25 Efficiency per i.h.p., per cent	20.63	24.32
26 Efficiency per net h.p., per cent	15.79	19.39
27 Efficiency per blast h.p., per cent	13.03	15.83
28 Dilution coefficient, per cent	2.267	2.686
29 Potential heat in exhaust per hr., B.t.u	11,159,000	6,178,480
30 Heat absorbed by jacket water per hr., B.t.u	3,481,200	2,998,690
31 Sensible heat in exhaust, etc., per hr. by difference, B.t.u	6,017,500	5,839,760

Distribution of Total Heat

32 Delivered to the blast, per cent	13.03	15.83
33 Pump work, per cent	4.84	4.93
34 Friction, per cent	2.76	3.56
35 Absorbed by jackets, per cent	13.38	15.11
36 Incomplete combustion, per cent	42.87	31.14
37 Balance by difference, per cent	23.12	29.43

TEST OF NO. 2 GAS ENGINE AT 27.5-LB. BLAST PRESSURE

1 Number of test	33	35
2 Date of test, 1909	April 13	April 14
3 Duration of test, min	60	60
4 Method of regulation	Bypass	Bypass
5 Sets of indicator diagrams	9	9
6 Venturi meter		
Pipe diameter, in	16, Area, 1.396 sq. ft.	
Throat diameter, in	6¼, Area, 0.213 sq. ft.	
7 Number of venturi observations	13	13
8 R.p.m. of engine	54.45	58.62
9 Gas pressure, in. water	11.01	10.94
10 P_1-P_2, in. water	38.88	51.65
11 Gas temperature, deg. fahr	62.6	42
12 Barometer, in. mercury	29.08	29.53
13 Absolute pipe pressure, lb. per sq. in	14.66976	14.88809
14 Absolute throat pressure, lb. per sq. in	13.26678	13.0243
15 Ratio $\frac{P_2}{P_1}$	0.90436	0.8748
16 $Mf\left(\frac{P_2}{P_1}\right)$	0.5025	0.5645

Jacket Water

Right Side

17 Water used per hr., lb	18,650	16,300
18 Temperature inlet, deg. fahr	42.3	40
19 Temperature discharge, deg. fahr	167.1	147.4

Left Side

20 Water used per hr., lb	20,000	17,650
21 Temperature inlet, deg. fahr	42.3	40
22 Temperature discharge, deg. fahr	169	156.4

Fuel Gas Analysis By Volume

23 CO_2 per cent	12.0	13.1
24 O, per cent	0.1	0.2
25 CO, per cent	25.9	24.3
26 H, per cent	0.5	1.4
27 N (by difference), per cent	51.5	61.0
28 Weight per cu. ft., standard conditions, lb	0.0832257	0.083047
29 Weight per cu. ft., test conditions, lb	0.0782805	0.0825485
30 Heating value per cu. ft., standard conditions, B.t.u.	90.054	87.721
31 Heating value per cu. ft., test conditions, B.t.u	84.7031	87.1661

EXHAUST GAS ANALYSIS BY VOLUME

Right Side

32 CO_2 per cent	12.1	12.1
33 O, per cent	8.5	8.7
34 CO, per cent	4.5	3.5
35 N (by difference), per cent	74.8	75.7

Left Side

36 CO_2, per cent	12.4	11 6
37 O, per cent	8.2	9.0
38 CO, per cent	4.1	3 4
39 N (by difference), per cent	75.3	76.0

CYLINDER PRESSURES AND HORSEPOWERS

Number of test	33	35
Date of test, 1909	April 13	April 14

MEAN EFFECTIVE PRESSURES

Motor		
Right head	51.74	51.90
Crank	53.42	55.37
Left head	56.44	59.59
Crank	55.59	59.01
Air pump		
Right head	4.88	5.79
Crank	4.92	5.79
Left head	5.61	6.88
Crank	5.20	6.34
Gas Pump		
Right head	4.64	5.47
Crank	4.85	5.46
Left head	5.34	6.32
Crank	5.12	6.06
Air tub		
Head	17.36	17.60
Crank	18.39	18.53

HORSEPOWERS

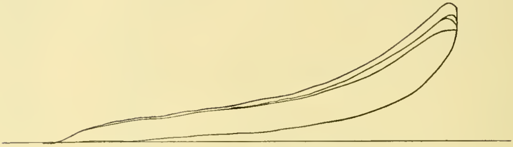
Motor		
Right head	463.44	500.47
Crank	478.48	533.93
Left head	505.53	574.63
Crank	497.92	569.03
Air pump		
Right head	37.33	47.69
Crank	37.51	47.52
Left head	42.92	56.66
Crank	39.64	52.03
Gas pump		
Right head	50.02	63.49
Crank	52.18	63.24
Left head	57.57	73.35
Crank	55.09	70.19
Air tub		
Head	649.67	709.10
Crank	680.61	738.31

RESULTS OF TESTS

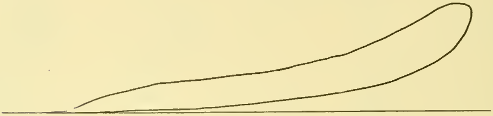
1	Number of test	33	35
2	Date of test, 1909	April 13	April 14
3	Method of regulation	Bypass	Bypass
4	Blast pressure, lb.	27.3	27.7
5	R.p.m. of engine	54.45	58.62
6	Gas per hr., standard conditions, cu. ft	279,512	325,429
7	Gas per hr., test conditions, cu. ft	297,170	327,501
8	B.t.u. per cu. ft., standard conditions	90.054	87.721
9	B.t.u. per cu. ft., test conditions	84.7031	87.1661
10	Total B.t.u. in gas per hr	25,171,200	28,546,970
11	I.h.p. of motor cylinders	1945.37	2178.06
12	I.h.p. of air pumps	157.40	203.90
13	I.h.p. of gas pumps	214.86	270.27
14	I.h.p. of blowing cylinder	1330.28	1447.41
15	I.h.p. net	1573.11	1703.89
16	I.h.p. friction	242.83	256.48
17	Gross mechanical efficiency of engine, per cent	87.52	88.22
18	Net mechanical efficiency of engine, per cent	68.38	66.45
19	Cu. ft. gas per i.h.p. hr., standard conditions	143.68	149.41
20	Cu. ft. gas per net h.p. hr., standard conditions	177.68	191.00
21	Cu. ft. gas per blast h.p.hr., standard conditions	210.12	224.84
22	B.t.u. per i.h.p-hr	12,939	13,107
23	B.t.u. per net h.p-hr	16,001	16,754
24	B.t.u. per blast h.p-hr	18,922	19,723
25	Efficiency per i.h.p., per cent	19.67	19.42
26	Efficiency per i.h.p., per cent	15.91	15.29
27	Efficiency per blast h.p., per cent	13.45	12.90
28	Dilution coefficient	1.947	2.1732
29	Potential heat in exhaust per hr., B.t.u	10,106,760	9,909,840
30	Heat absorbed by jacket water per hr., B.t.u	4,880,850	3,815,270
31	Sensible heat in exhaust, etc., per hr. by difference, B.t.u	5,323,710	9,277,765

Distribution of Total Heat

32	Delivered to the blast, per cent	13.45	12.90
33	Pump work, per cent	3.76	4.13
34	Friction, per cent	2.46	2.39
35	Absorbed by jackets, per cent	19.39	13.37
36	Incomplete combustion, per cent	39.79	34.71
37	Balance by difference, per cent	21.15	32.50

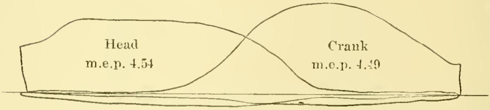


Right head - Scale 149.7, m.e.p. 37.63

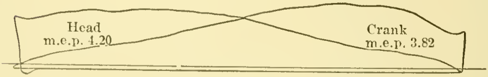


Left head - Scale 155.3, m.e.p. 38.82

Fig. 63*a* Average Motor Diagram—Test 37—5 Lb. Blast

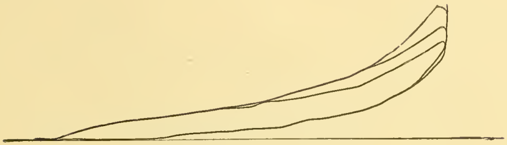


Right gas - Scale 10.35

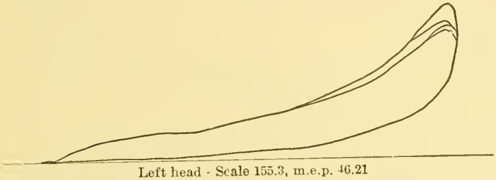


Right air - Scale 10.36

Fig. 63*b* Average Pump Diagram—Test 37—5 Lb. Blast

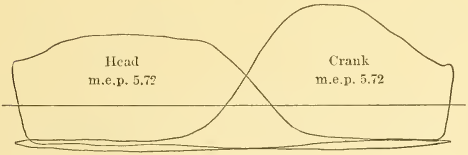


Right head - Scale 149.7, m.e.p. 31.45

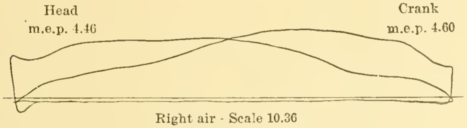


Left head - Scale 155.3, m.e.p. 46.21

FIG. 64*a* AVERAGE MOTOR DIAGRAM—TEST 28—10 LB. BLAST

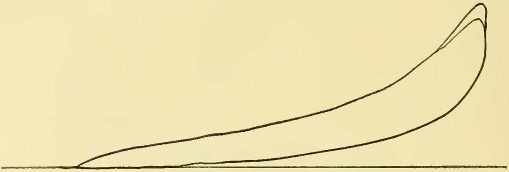


Right gas - Scale 10.35

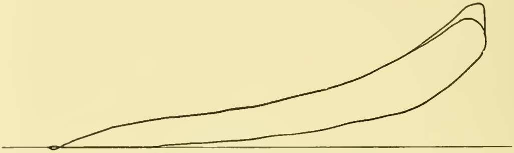


Right air - Scale 10.36

FIG. 64*b* AVERAGE PUMP DIAGRAM—TEST 28—10 LB. BLAST.

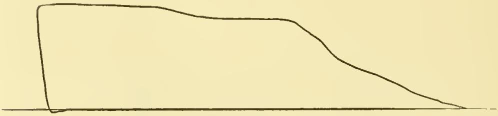


Right head - Scale 149.7, m.e.p. 44.15



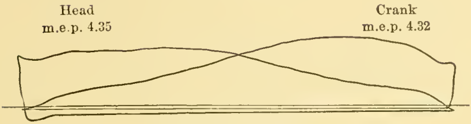
Left head - Scale 155.3, m.e.p. 42.35

FIG. 65*a* AVERAGE MOTOR DIAGRAM—TEST 30—15 LB. BLAST

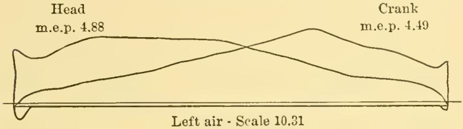


Crank - Scale 21.05, m.e.p. 12.60

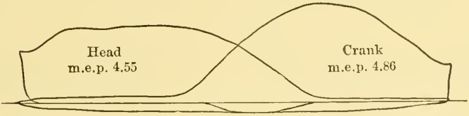
FIG. 65*b* AVERAGE COMPRESSOR DIAGRAM—TEST 30—15 LB. BLAST



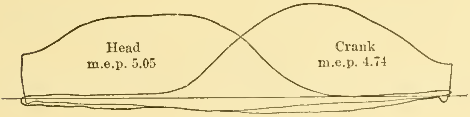
Right air - Scale 10.36



Left air - Scale 10.31

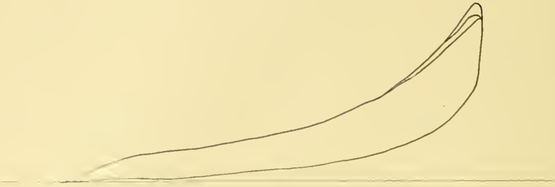


Left gas - Scale 10.35

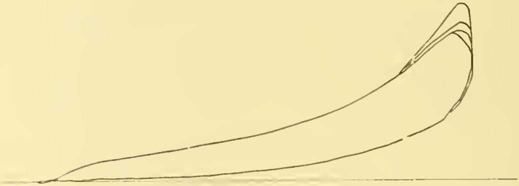


Left gas - Scale 10.44

Fig. 65c Average Pump Diagram—Test 30—15 Lb. Blast

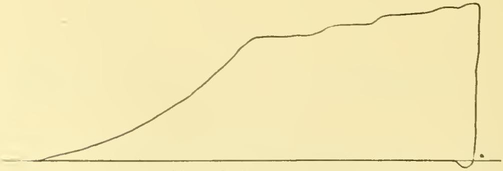


Right head - Scale 149.7, m.e.p. 48.92



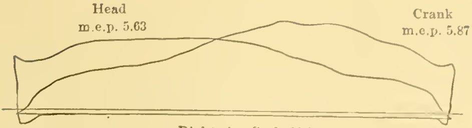
Left head - Scale 155.3, m.e.p. 52.63

FIG. 66*a* AVERAGE MOTOR DIAGRAM—TEST 32—20 LB. BLAST

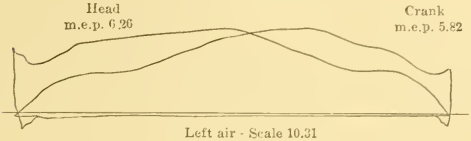


Head - Scale 20.4, m.e.p. 15.44

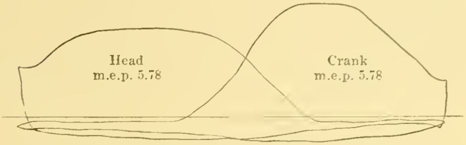
FIG. 66*b* AVERAGE COMPRESSOR DIAGRAM—TEST 32—20 LB. BLAST



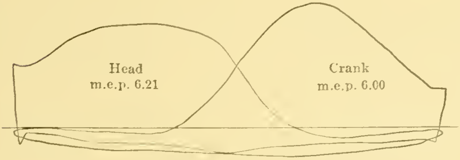
Right air - Scale 10.36



Left air - Scale 10.31

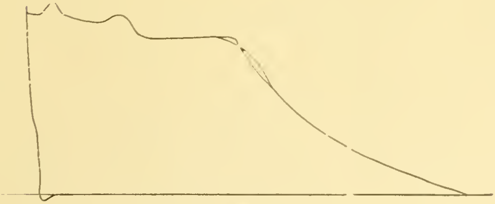


Right gas - Scale 10.35



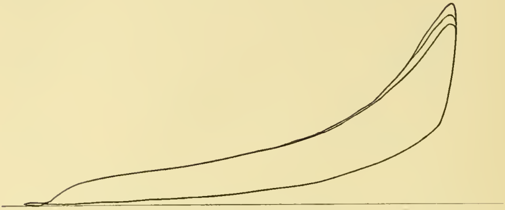
Left gas - Scale 10.44

FIG. 66*c* AVERAGE PUMP DIAGRAM—TEST 32—20 LB. BLAST

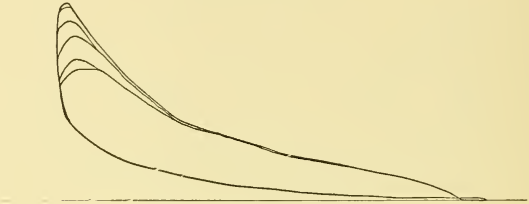


Crank - Scale 21.05, m.e.p. 18.58

FIG. 67*a* AVERAGE COMPRESSOR DIAGRAM—TEST 35—25 LB. BLAST

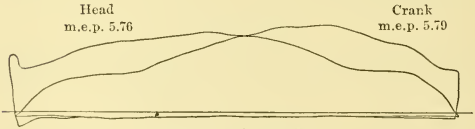


Right head - Scale 149.7, m.e.p. 52.14

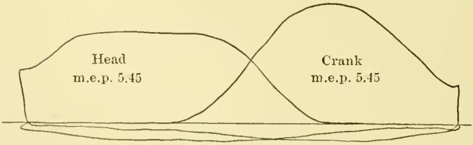


Left crank - Scale 161.9, m.e.p. 58.96

FIG. 67*b* AVERAGE MOTOR DIAGRAM—TEST 35—25 LB. BLAST



Right air - Scale 10.36



Right gas - Scale 10.35

FIG. 67*c* AVERAGE PUMP DIAGRAM—TEST 35—25 LB. BLAST

GENERAL NOTES

AMERICAN SOCIETY OF CIVIL ENGINEERS

The American Society of Civil Engineers has commenced its regular bimonthly meetings for the season of 1910-1911. At the gathering of October 5, E. G. Hopson, member of the society, presented a paper on the Tieton Canal; and on October 19, W. F. Strouse, member of the society, presented The Reconstruction of the Passenger Terminals at Washington, D. C.

In November, The Arch Principle in Engineering and Esthetic Aspects, and its Application to Long Spans, by C. R. Grimm, member of the society, will be discussed at the meeting on the first Wednesday evening in the month; and The Failure of the Yuba River Débris Barrier and the Efforts made for its Maintenance, by H. H. Wadsworth, member of the society, on the evening of the third Wednesday.

AMERICAN INSTITUTE OF MINING ENGINEERS

Plans for the Canal Zone meeting of the American Institute of Mining Engineers, to be held October 21-November 15, 1910, are proceeding satisfactorily and a large attendance is anticipated. Among the papers announced for presentation and discussion, probably on board ship en route to Panama, are Manganese Ore in Unusual Form, by William P. Blake; Crushing Machines for Cyanide Plants by Mark R. Lamb of Milwaukee; Labor-Saving Appliances in the Assay-Laboratory, by Edward Keller of Perth Amboy, N. J.; The Limit of Fuel Economy in the Blast-Furnace, by N. M. Langdon of Mancelona, Mich.; Dry Washing for Placer Gold in Sonora, by J. W. Richards, of Spokane, Wash.; Recent Developments in the Undercutting of Coal by Machinery, by E. W. Parker, Washington, D. C.; The Laws of Intrusion, by Blamey Stevens, Valdez, Alaska; Tests of an Ilgner Electric Hoist, by R. R. Seeber, Winona, Mich.; Bibliography to Accompany Paper on Electric Mine Hoists, by D. B. Rushmore, Mem.Am.Soc.M.E., and K. A. Pauly, Schenectady, N. Y.; Notes on Copper Blast-Furnace Tops, by N. H. Emmons, Copperhill, Tenn.; Mining in Nicaragua, by F. Lane Carter, Chicago, Ill.; Report of a Committee on Uniform Mining Laws for Prevention of Mine Accidents, by W. R. Ingalls, J. Parke Channing, James Douglas and John Hays Hammond, Mem.Am.Soc. M.E., New York, and James R. Finlay, Goldfield, Nev.; The Solid Non-Metallic Impurities in Steel, by Henry D. Hibbard, Mem.Am.Soc.M.E., Plainfield, N. J.; Theory of Dust Explosions, by Audley H. Stow, Maybeury, W. Va.; The Gold Fields of French Guiana and the New Method of Dredging, by A. F. J. Bordeaux, Thonon-Les-Bains, Savoie, France; The Agency of Manganese in the Superficial Alteration and Secondary Enrichment of Gold Deposits in the United States, by William H. Emmons of Chicago.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

The American Institute of Electrical Engineers held their first meeting of the year on Friday evening, October 14, at 8 p.m. in the Engineering Societies Building, New York. A paper was presented on Potential Strength in Dielectrics, by H. S. Osborne, of the American Telephone and Telegraph Company, and Prof. Harold Pender, of Massachusetts Institute of Technology.

On the invitation of the institute a public meeting at which all members of the engineering profession were welcomed was held on Monday evening, October 17, in the Engineering Societies Building. Rapid Transit Requirements of Greater New York, the subject for discussion, was informally presented by F. J. Sprague, Past-President A.I.E.E., and Chairman of the Railway Committee of the institute, in a paper covering the general facts pertaining to routes, construction and equipment of existing and proposed lines.

COURSES IN ARCHITECTURE IN ENGINEERING SOCIETIES BUILDING

Columbia University extension courses in Architecture are being given this year in the Engineering Societies Building, 29 West 39th Street, each weekday evening except Saturday. Three of the courses, mathematics, the history of architecture, and construction; are designed for students who have not had training, while the remainder are those of the first year of the School of Architecture and will count toward the diploma and degree in architecture for those who have passed the entrance examinations.

NATIONAL IRRIGATION CONGRESS

The 18th National Irrigation Congress, held in Pueblo, Colorado, in the Mineral Palace, opened on September 26 with an industrial parade. At the first session, called to order at 2.30 p.m., welcome was extended to the delegates by the Governor Shafroth of Colorado, and the Mayor of Pueblo, Hon. A. L. Fugard. Hon. B. A. Fowler, President of the Congress, responded, and Hon. Alva Adams, Former Governor of Colorado, gave an address on Colorado, Conquest and Conservation. Following an informal reception in the evening, Hon. William J. Bryan of Nebraska spoke on Irrigation and National Development. Tuesday morning was devoted to the consideration of Irrigation by Private Enterprise, with addresses by Hon. Frank C. Goudy, former president of the Congress, by Hon. John M. Wilson, Norman E. Webster, Jr., W. G. DeCelle, Dr. B. L. Jefferson, H. L. Moody, and Hon. George E. Barstow; and in the afternoon Hon. F. H. Newell, R. P. Teele, Gen. B. J. Viljoen, S. H. Lea, Hon. John A. Martin and Hon. John Fairweather spoke upon Public Irrigation. William E. Smythe addressed the evening meeting on The New Gospel: A Little Land and a Living. On Wednesday, W. K. Kavanaugh, Hon. Frank H. Short, Judge Joseph H. Kibbey, Judge George H. Hutton, Prof. E. B. House and James Cosgrove, spoke upon Water Equities; while in the afternoon, Irrigation Agriculture was discussed, with addresses by Albert F. Potter, Ernest Knabel, Dr. W. J. McGee, Col. E. J. Watson, Aaron Gove and Hon. Horace T. DeLong. An illuminated parade took place in the evening. The session of Thursday morning was given up to foreign representatives who brought messages from Austria-Hungary, Australia, Germany, Russia, Canada, British India, and Chili. General Policies were considered in the afternoon, on which occasion Mrs. H. L. Hollister, Hon. Gifford Pinchot, Hon. H. H. Eddy, and Hon. Francis J. Heney addressed the meeting. Problems of Irrigation Practice were discussed on Thursday evening by Prof. Samuel Fortier, Prof. W. B. Gregory, Mem.Am.Soc.M.E., and F. M. Webster. The concluding day of the Congress, Friday, Sept. 30, was devoted to the Governors' Session and to a business meeting at which Hon. B. A. Fowler was re-elected president for the ensuing year, and Arthur Hooker of Spokane chosen secretary.

The Society was represented at these meetings by C. H. Williams of Denver, Colo.

ENGINEERS CLUB OF ST. LOUIS

At the regular meeting of the Engineers Club of St. Louis held on October 5 in the club rooms, J. W. Woermann, Assistant Engineer, Western Division, U. S. A., presented a paper entitled The Deep Waterway—St. Louis to Cairo, giving a review of seven plans suggested for securing a 14-foot depth of channel in the Mississippi River.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS

The 17th annual convention of the American Society of Municipal Improvements was held in the Chamber of Commerce rooms, Erie, Pa., October 11-14. Among the papers presented were European Sewage Disposal, Dr. Rudolph Hering, Mem.Am.Soc. M.E.; Laying Asphalt with a Surface Heated, by B. B. Colburn; Modern Stone Block Pavements, by Wm. A. Howell; The Economics of Modern Highway Engineering, by Prof. A. H. Blanchard; and Taxation, by A. W. Heston. Trips of inspection were made to various points of engineering interest in and about Erie, and an excursion by boat taken through Presque Isle Bay. One of the features of the convention was an exhibit arranged by dealers and manufacturers of municipal appliances.

BROOKLYN ENGINEERS CLUB

William T. Donnelly, Mem. Am. Soc. M.E., presented a paper, illustrated by lantern slides, upon Electrification of the John N. Robins Company, Erie Basin, Brooklyn, N. Y., at the regular meeting of the Brooklyn Engineers Club, on Thursday evening, October 13, 1910, at the Club House in Remsen Street. The paper dealt principally with floating and basin dry dock equipment, compressed air, shop motors and high tension distribution system. On October 20, an informal library talk was given on the Air Compressor by Snowden Redfield, Associate Editor of the American Machinist, which was illustrated with stereoptican views.

AMERICAN GAS INSTITUTE

The 5th annual meeting of the American Gas Institute was held in the auditorium of the Engineering Societies Building, 29 West 39th Street, New York, October 19-21, 1910. Professional sessions occupied both the opening days, while the last day was devoted to a steamboat excursion. On Wednesday evening the members were the guests of the New York Edison Company at the Electrical Show in progress at Madison Square Garden, where the special exhibit of the company was reserved for the exclusive use of the party until 10 p.m. John W. Lieb, Jr., Mem. Am. Soc. M.E., delivered an address. On Thursday evening a banquet was given at the Hotel Astor for the members of the institute and the visiting ladies were entertained at a theatre party.

Among the papers presented at the business sessions were Manufacture of Balloon Gas in Water Gas Apparatus, by George H. Waring; Construction of a Reinforced Concrete Tank for a Gas Holder, by V. L. Elbert; Apparatus Designed for Remote Control of District Pressure, J. S. Kennedy; A Review of Recent Decisions of the Public Service Commissions which affect Gas Companies, by A. E. Forstall, Mem.Am.Soc.M.E.; and The Public Deceived by Faulty Data and Misleading Analysis of Data, by Dr. A. C. Humphreys, Mem. Am. Soc. M.E.

AMERICAN IRON AND STEEL INSTITUTE

The first formal meeting of the American Iron and Steel Institute Convention was held in the Waldorf-Astoria Hotel, New York City, on October 14. Elbert H. Gary, President of the institute, and Chairman of the United States Steel Corporation, presided at the professional sessions and at the banquet on Friday evening, the principal feature of which was a lecture on the Gary plant of the United States Steel Corporation, given by G. G. Thorp, Mem.Am.Soc. M.E., Vice-President of the Indiana Steel Company. On Saturday, October 15, a tour was made of New York harbor, starting from the New York Central and Hudson River Railroad's pier in the Hudson River, proceeding through New York bay to Staten Island and into Kill von Kull, and returning by the Narrows through the East and Harlem Rivers into the Hudson. Landings were made en route at Ellis Island, the Bush Terminal in South Brooklyn, and the Navy Yard.

On Sunday the members and guests left New York by special train for Buffalo where they visited the plant of the Lackawanna Steel Company; Black Rock, where the mammoth lock is being built for the new ship canal; the power plants at Niagara Falls; and Niagara Gorge. Proceeding to Chicago, the party spent several days there, inspecting the plants of the Indiana Steel Company, the Illinois Steel Company, the McCormick Works of the International Harvester Company, the Pullman Company, the Union Stock Yards, and other places of interest. On October 18 a dinner was given at the Blackstone Hotel at which Judge Gary presided. At Pittsburg, where the party arrived on October 20, trips were made to the Jones and Laughlin Steel Company, the Carnegie Steel Company, the Carnegie Institute and Technical Schools, and the Westinghouse plants; and informal dinners were served on Thursday and Friday evenings at the Hotel Schenley. The final stop of the tour was in Washington, D. C., where the leading event was a reception tendered by President Taft at the White House on October 22. The special train conveyed the party to New York on October 23.

In addition to the members present at the meetings and on the tour, about thirty leading iron and steel masters of Great Britain and Europe were in attendance as guests of honor. The committee in charge of the arrangements for the entire period consisted of E. A. S. Clarke, President of the Lackawanna Steel Company, Chairman; James Farrel, President of the United States Steel Products Company; and John A. Topping, President of the Republic Iron and Steel Company.

AMERICAN BOILER MANUFACTURERS ASSOCIATION

The American Boiler Manufacturers Association held its 22d annual meeting at the Auditorium Hotel, Chicago, on October 10-13, 1910, electing the following officers: President, Col. E. D. Meier, Vice-President Am.Soc. M.E., of New York; Secretary, J. D. Farasey of Cleveland; Treasurer, Jos. F. Wangler of St. Louis. Colonel Meier presided at the professional sessions and at the banquet on Thursday evening. The association appointed a committee to investigate and report at its next meeting on the standardization of boilers, as a result of discussion brought up on this subject. During the meeting a trip was made to the Illinois Steel Company plant at Gary, Indiana.

THE AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION

The annual convention of the American Street and Interurban Railway Association was held at Atlantic City, N. J., October 10-14, with headquarters at the Greek Temple, Convention Pier. There were papers read on the following subjects: Creation of Passenger Traffic, J. F. Keys; The Use of Metal Tickets, G. L. Radcliffe; Transfer Laws and Suggested Changes, L. S. Hoffman. Various committees also reported on Passenger Traffic, Interurban Rules, Express and Freight Traffic, City Rules, Transfer and Transfer Information, Training of Transportation Employees, Construction of Schedules and Time Tables, Heavy Electric Traffic and Detail Records: Their Use and Value.

PERSONALS

L. B. Alexander has entered the employ of the Bosch Magneto Co., New York, as assistant chief of department. Until recently, Mr. Alexander was vice-president of the Haggerty Contracting Co., New York.

J. F. Beecher, formerly associated with the Pennsylvania Steel Co., Harrisburg, Pa., as checker of the mechanical department, has accepted a similar position with the Indiana Steel Co., Gary, Ind.

George Berna, formerly president of the Hygeia Ice Co., Ithaca, N. Y., has become identified with the Modern Ice Machinery Co., San Antonio, Tex.

Geo. A. Buvinger has accepted a position with the Allis-Chalmers Co., West Allis, Wis., in the capacity of designing engineer for centrifugal pumps. Mr. Buvinger was recently associated with the D'Olier Engineering Co., Philadelphia, Pa., as hydraulic engineer.

V. Z. Caracristi, formerly general maintenance supervisor in charge of the upkeep on tools, buildings and equipment of the plants of the American Locomotive Co., and assistant machinery supervisor on purchase of new tools and equipment and general betterment and improvement work, has become consulting engineer of the Wheeling and Lake Erie R. R. Co., Massillon, O.

W. Van Alan Clark has accepted a position with the Astoria Light, Heat and Power Co., Astoria, L. I., N. Y., as engineer's assistant. Until recently he was draftsman and inspector of construction work, Matawan, N. J.

Geo. E. Crofoot has become associated with the Browning Engineering Co., Cleveland, O. He was formerly instructor in mechanical engineering at the University of Pennsylvania, Philadelphia, Pa.

Henry D. Fisher, recently associated with the U. S. Glass Co., Pittsburg, Pa., in the capacity of supervising engineer, has become connected with the Fuel Testing Co., Boston, Mass.

Perry J. Freeman, formerly instructor in mechanical engineering at the University of Pennsylvania, Philadelphia, Pa., is now in charge of all the shops of the department of mechanical engineering of the University of Illinois, Urbana, Ill.

Albert W. Jacobi has opened an engineering office in Newark, N. J. He was formerly connected with the Tide Water Oil Co., Bayonne, N. J.

Edward K. Junghans has severed his connection with the Porvenir Sugar Co., San Pedro, S. D., and has accepted the position of chief engineer of the Central Mercedita, Ponce, P. R.

A. G. Kessler, formerly instructor in the department of power engineering, Sibley College, Cornell University, Ithaca, N. Y., has become associated with the engineering department of R. G. Peter's Manufacturing Co., Grand Rapids, Mich.

Morris Knowles, recently chief engineer of the Bureau of Filtration, City of Pittsburg, Pa., has opened offices in the Oliver Building, Pittsburg, Pa., for the practice of general and consulting civil engineering, particularly in the important branches relating to municipal, sanitary and hydraulic work.

L. R. Lemoine, formerly general manager of the N. J. Zinc Co., New York, has been appointed 2nd vice-president of the U. S. Cast Iron Pipe and Foundry Co., with headquarters at Philadelphia, Pa.

Samuel T. Mudge has entered the employ of the Rogers Paper Manufacturing Co., South Manchester, Conn., as superintendent. He was recently instructor in mechanical engineering at the University of Michigan, Ann Arbor, Mich.

Henry S. Otto has become superintendent of the Saurer Motor Trucks, Chicago, Ill. He was formerly identified with Munroe & Co., Paris, France.

Harold L. Pope has accepted a position with the Pope Manufacturing Co., West Works, Hartford, Conn., in the capacity of manager. He was recently identified with the Matheson Motor Car Co., Wilkes-Barre, Pa.

E. Posselt, formerly connected with the St. Louis Portland Cement Works, St. Louis, Mo., as assistant manager, has accepted the position of chief engineer of the Cement Securities Co. of Denver, Colo.

Walter I. Slichter has been appointed professor of electrical engineering at Columbia University, New York. He was until recently associated with the General Electric Co., Schenectady, N. Y., as technical assistant to the vice-president and chief engineer of the company, and also a member of the staff of consulting engineers of the company.

T. Carlile Ulbricht has been appointed instructor in the department of power engineering, Sibley College, Cornell University, Ithaca, N. Y. He was formerly assistant instructor in applied mechanics at Pratt Institute, Brooklyn, N. Y.

Louis R. Valentine, formerly associated with the Charles Warner Co., Phoenixville, Pa., has become identified with the Security Cement and Lime Co., Security, Md.

C. C. Wilcox has accepted a position as assistant to the consulting electrical engineer for Hodenpyl, Walbridge & Co. of New York, with office in Detroit, Mich. Mr. Wilcox was formerly connected with the Michigan Agricultural College, East Lansing, Mich., as foreman of machine shop and instructor in thermodynamics.

William F. Zimmermann, recently located in Spokane, Wash., has become identified with the Pittsburg Testing Laboratory as 2nd vice-president, with headquarters in New York.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

ANNALES DES PONTS ET CHAUSSÉES. Ser. 8. Vol. 8. 2 pts. *Paris, 1908.*

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION. Report of the Proceedings of the 42d Annual Convention, 1909. *Chicago, 1909.* Gift of the association.

CIVIL ENGINEERS SOCIETY OF ST. PAUL, MINN. List of Members, 1910. *St. Paul, 1910.* Gift of the society.

COLORADO ELECTRIC LIGHT, POWER AND RAILWAY ASSOCIATION. Report of Committee on Grounding Secondaries. By J. A. Clay and others. Gift of the association.

COMPRESSED AIR, THEORY AND COMPUTATIONS. By E. G. Harris. *New York, McGraw-Hill Book Co., 1910.*

CONSTRUCTION OF GRAPHICAL CHARTS. By J. B. Peddle. *New York, McGraw-Hill Book Co., 1910.*

CREOSOTE TREATMENT OF OUR NATIVE LODGEPOLE PINE POLES. By G. R. Ogier. Read before the Colorado Electric Light, Power and Railway Association, September 21–23, 1910, and presented by the assoiation.

ECONOMIC NECESSITY FOR THE PENNSYLVANIA RAILROAD TUNNEL EXTENSION INTO NEW YORK CITY. By A. J. County. (Reprinted from the Annals of the American Academy of Political and Social Science, March 1907.) *Philadelphia.* Gift of the company.

EDINBURGH UNIVERSITY. Calendar, 1910–1911. *Edinburgh, 1910.* Gift of the university.

ELECTRIC MOTORS, CONTINUOUS, POLYPHASE, AND SINGLE-PHASE MOTORS, THEIR THEORY AND CONSTRUCTION. By H. M. Hobart. Ed. 2. *New York, Macmillan Co., 1910.*

FACTORY ORGANIZATION AND ADMINISTRATION. By Hugo Diemer. *New York, McGraw-Hill Book Co., 1910.*

GREAT BRITAIN PATENT OFFICE. Catalogue of the Library—Authors. *London 1910.* Gift of Great Britain Patent Office.

HIGH-SPEED STEEL. By O. M. Becker. *New York, McGraw-Hill Book Co., 1910.*

INTERNATIONAL ELECTROTECHNICAL COMMISSION. First Annual Report, to December 31, 1909. *London, 1910.* Gift of the commission.

——Resumé of Unofficial Conference held at Brussels, August, 1910. *London, 1910.* Gift of the commission.

——TRANSACTIONS OF THE COUNCIL HELD IN OCTOBER 1908. *London, 1909.* Gift of the commission.

Lighting Engineers' Hand-Book. Compiled by L. R. Pomeroy. *New York, Safety Car Heating & Lighting Co., 1909.*

Mazda Series Street Lighting. By H. L. Aller. Read before the Colorado Electric Light, Power and Railway Association, September 21–23, 1910, and presented by the association.

Mechanical Engineers' Pocket Book. By M. Kent. Ed. 8. *New York, J. Wiley & Sons, 1910.*

New York City Board of Water Supply. Construction of Seven Steel-Pipe Siphons and Adjacent Portions of the Catskill Aqueduct in the Towns of Yorktown, Mt. Pleasant and Greenburg, and in the City of Yonkers, Westchester Co., New York. Gift of New York City Board of Water Supply.

——Contract Drawings. *1909.* Gift of New York City Board of Water Supply.

New York Improvement and Tunnel Extension of the Pennsylvania Railroad. August, 1910. *Philadelphia, 1910.* Gift of the company.

New York Tunnel Extension of the Pennsylvania Railroad. Introductory Paper by C. W. Raymond and the East River Division by A. Noble. (Reprint from Trans. Am. Soc. C. E., Vol. 35, 1909.) Gift of the company.

New York (State) Engineer and Surveyor. Annual Report. 1905 and Supplement. Vol. 1–2. 1906 and Supplement. 1907–1909. *Albany, 1906, 1910.* Gift of New York State Engineer and Surveyor.

Pennsylvania Railroad New York Tunnel Extension, Historical Outline. December 1909. Gift of the company.

Railway Library, 1909. Compiled and Edited by Slason Thompson. *Chicago, 1910.* Gift of the author.

Railway Storekeepers Association. Seventh Annual Meeting, 1910. *St. Louis, 1910.* Gift of the association.

Rossiter Worthington Raymond, 1840–1910. Dinner given by his friends in commemoration of his 70th birthday. *New York, 1901.* Gift of C. W. Rice.

Report on Natural Gas Service Rendered the City of Columbus, Ohio, by the Columbus Gas and Fuel Company. By E. A. Hitchcock and S. S. Wyer. Gift of the authors.

Rotary Condensers and Induction Generators on Transmission Systems. By A. L. Jones. (Read before the Colorado Electric Light, Power and Railway Association, September 21–23, 1910.) Gift of the association.

Royal Automobile Club. Year Book, 1909. *London, 1909.* Gift of C. W. Rice.

Russian Turkestan and Its Products. By N. J. Malahowski. *St. Petersburg, 1910.* Gift of the author.

Some Observations on Cultivating Friendly Relations with the Public. By J. M. Connelly. Read before the Colorado Electric Light, Power and Railway Association, September 21–23, 1910, and presented by the association.

Standard Handbook for Electrical Engineers. Ed. 3. *New York, McGraw-Hill Book Co., 1910.*

STEAM TURBINES. By E. W. Gilbert. Read before the Colorado Light, Power and Railway Association, September 21–23, 1910, and presented by the association.

JAMES WATT OF SOHO AND HEATHFIELD. Annals of Industry and Genius. By T. E. Pemberton. *Birmingham 1905.* Gift of Geo. Tangye.

WEITERE VERSUCHE ZUR ERMITTLUNG DES KRAFTBEDARFS AN WALZWERKEN. By J. Puppe. *Düsseldorf, 1910.* Gift of Verein deutscher Eisenhüttenleute.

WESTERN RAILWAY CLUB. Official Proceedings. Vol. 22. *Chicago, 1910.* Gift of the club.

YALE UNIVERSITY. Report of the Treasurer, 1909–10. *New Haven, 1910.* Gift of the university.

EXCHANGES

BETON UND EISEN. Year 6–8, 9. Nos. 1–11. *Berlin, 1907–1910.*

INSTITUTION OF CIVIL ENGINEERS OF IRELAND. Transactions. Vol. 34. *Dublin, 1908.*

INSTITUTION OF NAVAL ARCHITECTS. Transactions. Vol. 52, 1910. *London, 1910.*

INTERNATIONAL ASSOCIATION FOR TESTING MATERIALS, BRUSSELS CONGRESS, 1906.

———On Accelerated Tests of the Constancy of Volume of Cements. By B. Blount.

———Allotropic Transformations of Nickel Steels. By M. O. Boudouard.

———Alloys of Iron and Nickel. By Dr. H. Wedding.

———Apparation of the Neutral Fibre in Transparent Bodies by Means of Circularly Polarized Light. By O. Honigsberg.

———On the Basis of Existing Specifications to Seek Methods and Means for the Introduction of International Specifications for Testing and Inspecting Iron and Steel of all kinds. (Proposed at the Zürick Congress 1895. Enlarged at the Budapest Congress 1901. By A. Rieppel.

———On the Behavior of Cements in Sea Water. By H. Le Chatelier.

———Bending-tests with Notched Specimens of Metals. By G. Charpy.

———Brinell Hardness-test and its Practical Application. By J. A. Brinell and G. Dillner.

———From Communication 8 of the Danisk State Testing Institute on Tests with Steam, Gas and Water-tubes. By H. J. Hannover.

———Communication on Methods for the Rapid Testing of Metals. By M. R. Guillery.

———Contribution to the Discussion of Special Steels. By M. Leon Guillet.

———Contribution to the Discussion on the Testing of Lubricating Oils. By M. P. Breuil.

———Contribution to the Discussion on the Testing of Wood. By M. P. Breuil.

———Contribution to the Discussion on Welding and Soldering. By M. P. Breuil.

———Determination of a Uniform Method for the Separation of the Finest Particles in Portland Cement by Liquid and Air Processes. By M. Gary.

——Determination of the Degree of Fragility and of Homogeneity of Rail-Steel by Impact-test with Notched Bars (Ast-Barba). Summary. By S. Drouginine.

——Determination of the Liter Weight of Cement. The Strength of Real Hydraulic Cements. Determination of a Standard Sand. By F. Schüle.

——Determination of the Points of Allotropic Transformation in Iron and its Alloys by Measurement of the Variations in their Electrical Resistance at Different Temperatures. By M. O. Boudouard.

——On the Determination of the Specific Gravity of Cements. By G. Baire.

——Discussion on Special Steel. By L. Dumas.

——Examination and Evaluation of the Resolutions of the Conferences of 1884–1893 concerning the Adhesive Strength of Hydraulic Cements. By R. Feret.

——Examination of Various Metals by Brinell's Method. By M. P. Breuil.

——Experiment on Lead and Copper Subjected to Compression in Three Impact Machines. By W. K. Hatt.

——Experiments on the Elasticity of Some Sicilian Limestones. By M. Greco.

——Experiments on the Resistance to Shearing of Cement Mortars. By M. Greco.

——Financial Returns for the years 1901–1905, Supplement to the Chairman's Report. By F. Berger.

——Fixing Uniform Definition and Nomenclature of Bitumen. By G. Lunge.

——Frictional Resistance on Lubricated Surfaces. By F. Kick.

——Graphic Representation of the Process of Setting in the Case of Cements.

——Influence of Temperature on the Fragility of Metals. By M. G. Charpy.

——On the International Researches in Microscopic Examination (etching tests) of Iron. By W. Ast.

——On the Measurement of the Stresses Set up in Rails During the Passage of a Train. By J. Schroeder v.d. Kolk.

——Mechanical Examination of Manufactured India-Rubber. By P. Breuil.

——Mechanism of the Deterioration of Cement Mortars, and the Rapid Determination of their Behaviour in the Sea by the Manner in which they Decompose. By M. Maynard.

——Methods for the Examination of Welding and Weldability. By R. Krohn.

——Methods for Testing Pipes. By M. Gary.

——Methods of Testing Metals and Alloys, Hydraulic Cements and Woods, Clay, Stoneware, and Cement Pipes.

——Methods of Testing the Protective Power of Paints Used on Metallic Structures. By E. Ebert. Annex. Raw and Boiled Linseed Oil. By A. Grittner.

——Model Testing Laboratory Installed and Exhibited During the Fourth Congress of the International Association for Testing Materials, Brussels, 1906.

———Necessity of Modifying the Process Actually Followed in Analysing Cement Mortars and in Sampling them. By M. Maynard.

———New Apparatus for Automatically drawing the Load-Strain Diagram due to Impact. By A. Gagarine.

———New Dynamometer Determination of the Yield-Point as a Test-Method. Description of a Machine for Compression, Tension, and Bending Tests. By A. Gagarine.

———New Method of Testing Magnetic Metals. By L. Fraichet.

———New Weathering Tests with Natural Stones. By M. Gary.

———Normal Consistency of Cement Mortars. By J. Malüga.

———Notes on the Examination of Powdered Asphalt. By Dr. Holde.

———Observations Regarding the Mechanical Examination of Iron by Means of Drop-tests with Notched Bars. By C. J. Snyders.

———Official Report of the Proceedings of the Fourth Congress of the International Association for Testing Materials, 1906.

———Phenomena of Deformation and Rupture in Iron and Mild Steel. By F. Osmond.

———Principles of a Standard Method of Testing Wood. By M. Rudeloff.

———Punching as a Testing Method. By M. L. Baclé.

———Relation of Chemical Composition to the Weathering Qualities of Building Stones; the Influence of Smoke Especially Sulphurous Acid on Building Stones; the Weathering Qualitites of Roofing Slates.

———Relation of Timber-tests to Forest Products. By W. K. Hatt.

———Remarks on the Influence of the Shape of the Saw-Notch in the Present Method of Testing for Fragility. By F. Barbier.

———Report on Impact-tests on Notched Bars. By E. Sauvage.

———Report on Methods of Etching Malleable Iron for the Visual Investigation of Structure; and on the Lessons to be learnt therefrom. By E. Heyn.

———Report on the Progress of Metallography since the Congress at Budapest, 1901. By F. Osmond and G. Cartaud. Supplement. By F. Osmond.

———Report on the Work of Committee 22, Appointed for the Solution of the Unification of Testing Methods. By N. Belelubsky.

———Report on the Work of the Council From the Budapest to the Brussels Congress, 1901–1906. By F. Berger.

———Report on Trials made at La Rochelle on the Action of Sea-Waters on Mortars. By E. Mayer.

———Resistance of Stone to Compression, with Elastic Substances Interposed Between the Surfaces in Compression. By G. S. Pace.

———Results of Trials with Timber Carried out at the Austrian Forestry Testing-Station at Mariabrunn. By G. Janka.

———Significance and Importance of Contraction as a Test for Quality Especially in Estimating the Malleability of Metals. By St. Gallik.

———Simple Method of Adapting the Principle of Automatic Registration to Lever-Testing Machines. By A. Mesnager.

———Study of the Methods of Testing Caoutchouc. By E. Camerman.

———Tests of the Decomposition of Cement Mortars by Sea-Water and Waters Containing Sulphates. By A. Bauchère.

———Tests upon Notched Bars Carried out in the Laboratory de l'Ecole des Ponts et Chaussées, Paris. By M. Mesanger.

———To Establish Methods for Testing Puzzolanas with the object of Determining their Value for Mortars. By G. Herfeldt. Annex. Experiments made in the Laboratoire des Ponts et Chaussées de Boulogne sur Mer with the View of Determining the Methods for Testing Puzzuolanas. By R. Feret.

———To Establish Methods of Inspection and Testing for Determining the Uniformity of Individual Shipments of Iron and Steel. By W. Ast.

———To Establish Uniform Methods of Testing Cast Iron and Finished Castings. By R. Moldenke.

———Transmission of Forces to the Interior of Elastic Solids. By M. Mesnager.

———On the Uniform Nomenclature of Iron and Steel. By H. M. Howe and A. Sauveur.

———Unmittelbare Abbildung der Neutralen Schichte bei Biegung Durchsichtiger Korper in Zirkularpolarisiertem Licht. By O. Hönigsberg.

North-East Coast Institution of Engineers and Shipbuilders. Transactions. Vol. 26. *Newcastle-upon-Tyne,* 1910.

Record of the Special Commission formed by the British Fire Prevention Committee to visit Berlin, Hamburg and Hanover on the Occasion of A Meeting of the German Professional Fire Service Association (Hamburg, 1909). Being a Diary and Notes. Compiled by E. O. Sachs and E. Marsland. (British Fire Prevention Committee.) *London.* Journal No. 5, 1910.

TRADE CATALOGUES

Broderick & Bascom Rope Co., *New York, N. Y.* Automatic loader system of aerial wire rope tramways, 15 pp.

Thos. Carlin's Sons Co., *Pittsburg, Pa.* Shears for rolling mills, forges, scrap yards, etc., 22 pp.; Hoisting engines and derricks, 70 pp.; Grinding machinery, 15 pp.

F. H. Evans, *Brooklyn, N. Y.* "Crescent" Expansion bolts, 12 pp.

H. W. Johns-Manville Co., *Cleveland, O.* J.-M. Roofing Salesman, September 1910, 8 pp.; J.-M. Packing Expert, September 1910, 4 pp.

Link-Belt Co., *Philadelphia, Pa.* Silent chain for power transmission, 40 pp.

Massachusetts State Boiler Board, *Boston, Mass.* Boiler manufacturers authorized to construct Massachusetts standard boiler, 14 pp.

North Western Expanded Metal Co., *Chicago, Ill.* Designing data for reinforced concrete, 48 pp.

Joseph T. Ryerson & Co., *New York, N. Y.* Monthly Journal and Stock List, October, 1910, 144 pp.

Sims Co., *Erie, Pa.* By-Pass open feed water heater, filter, oil separator and receiver. 12 pp.

Underfeed Stoker Co. of America, *Chicago, Ill.* Publicity Magazine, September 1910, 15 pp.; October 1910, 16 pp.

Union Fibre Co., *Winona, Minn.* Linofelt, 64 pp.; Cold storage insulation, 32 pp.

UNITED ENGINEERING SOCIETY

AMERICAN TRADE INDEX. (Domestic Edition.) 1908–1910. *New York, 1910.* Gift of National Association of Manufacturers.

BREAKDOWN CONNECTIONS TO ISOLATED PLANTS. By M. F. McAlpin. *New York, 1910.* Gift of the author.

DEUTSCHER VEREIN VON GAS UND WASSERFACHMÄNNERN. VERHANDLUNGEN. 1891–1901. *München, 1892–1902.*

POOR'S MANUAL OF RAILROADS, 1910. *New York, 1910.*

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

051 Urgent need of man thoroughly competent on all questions of gear cutting. Must know thoroughly the bevel, spur and worm gear theory and practice and be able to handle men.

052 Experienced general foreman to manage about one hundred men in the manufacture of single, duplex and power pumps. Location Ohio.

053 Engineer to take charge of construction. Must have some knowledge of gas engine and electrical practice, able to design and superintend new buildings of simple character; growing plant consisting of foundries and machine shops employing 800 hands in town of 18,000 inhabitants in Schuylkill valley, 40 miles from Philadelphia.

054 Wanted, by a New York company, up-to-date, energetic salesman for combustion work. New York territory.

055 Old established manufacturing business needs a business manager, able to take an interest of ten to twenty thousand dollars. Engineering features can be eliminated or separated. Attractive profits have been made for thirty years. Present manager would give part time for one or two years when needed.

056 Exceptional opportunity is offered to a mechanical engineer of executive ability who will invest a few thousand dollars and have the management of a company manufacturing a perforated steel band drive (Patented), capable of limitless use in the textile and many other trades. This company will also manufacture and market machinery improved and simplified by use of such band device for the textile trades.

MEN AVAILABLE

127 Sales engineer, seven years varied engineering experience and six years in selling end. Would consider position where knowledge of machinery and mill supply trade of the United States and Canada is essential. Experience in correspondence and proper design of selling contracts.

128 Young engineer, married, Junior member, graduate Stevens, with valuable experience in operation end of manufacturing concerns, erection, maintenance and repair of steel mills, decorticating, saw mill, textile, coal handling, and power plant machinery, desires position in executive capacity with first-class concern manufacturing machinery in these or associated lines. Location East or Middle West.

129 Junior member, college graduate, at present holding high executive position would like to affiliate with some large engineering concern. Wide experience in steam, electric and hydraulic work. Particularly familiar with textile machinery. Would consider superintendency of large bleachery.

130 Mechanical engineer and designer. Ten years broad practical experience. Design and construction of hydro-electric power plants, electric railroads, industrial and power plant mechanical equipment, foundations, special mechanical devices and machine design, gas engines and aeronautical work. Technical education; executive ability. Desires position as mechanical engineer or superintendent with gas engines builders. At present employed.

131 Graduate mechanical and electrical engineer, practical mechanic, several years of broad industrial experience, wishes to secure position where energy, ability and "push" are the qualities most desired and recognized. Thoroughly experienced in ice-making and refrigeration. At present located in Southern city. Salary commensurate with importance of position. Permanency preferred and sought.

132 Member, technical education and training, twelve years experience machine, mill and power house design, inspecting and estimating, corresponding, office work, etc. Desires change of position, southern California preferred, but not essential.

133 New York member, age 37, technical graduate, broad experience covering shop-costs, catalog writing, advertising, business corresponding and engineer-salesman. For several years in general charge of sales department of large concern. Now engaged in special line; desires executive position with progressive company, preferably with chance of acquiring an interest.

134 Technical graduate in electrical engineering and manual training school, with additional shop, drafting room and office practice; desires position in office where such experience will be of advantage.

135 Associate, age 32, at present engaged as engineer with large manufac-

turing concern, desires to change. Construction, operation, general engineering and executive experience.

136 Junior, experienced on boiler design, construction and estimating. Technical graduate, familiar with modern boiler shop and foundry methods, good organizer. At present chief draftsman and engineer. Desires similar position or assistant superintendent.

137 Member desires position as superintendent or manager. Technical graduate with wide practical experience in the machine shop, foundry and business. Now employed on staff of a production engineer, but prefers position with fixed residence.

138 Member, technical graduate, charge of large shops as superintendent and manager, also estimating cost systems, correspondence etc., thorough experience in design, construction and economical operation of power and manufacturing plants. Several years experience as sales manager Corliss engines; also as general sales manager water tube boilers. Desires position with chance to secure an interest. Engaged in special work at present but desires permanency.

139 Member, technical graduate, practical mechanic, with wide experience in the design, manufacture and sales of boilers, both water tube and return tubular, self supporting stacks, breechings, tanks, etc., and also design and installation of complete power plants, desires position where above knowledge can be put to best use. Can handle shop, office or sales and desires a permanent position. If connection is mutually satisfactory could invest some money in the company.

140 Junior member, graduate of Massachusetts Institute of Technology, M.E.; four years in practical shop work, general drafting and minor executive; desires position as draftsman with consulting engineers or as assistant to superintendent of industrial plant.

141 Internal combustion engine salesman and manager, 34 years of age. Eight years experience, particularly in the oil engine branch of business; desires position with aggressive, growing concern, on developing or building oil engines preferred. Suitable references furnished.

142 M.E. Virginia Polytechnic Institute and Cornell, at present with structural steel concern as draftsman, desires position with consulting and contracting engineers; experience in machine tool design, steel mill and blast furnace construction.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ADAMS, Thomas D. (Junior, 1906), Werner & Pfleiderer, Saginaw, Mich., and *for mail*, Southport, Conn.

ALEXANDER, Ludwell Brooke (Junior, 1905), Asst. Ch. of Dept., Bosch Magneto Co., 223 W. 46th St., and *for mail*, Cliffwood Court, 179th St. and Ft. Washington Ave., New York, N. Y.

APPLETON, Henry W. (Junior, 1906), Mech. Supt., Passaic Print Wks., and *for mail*, 243 Van Houten Ave., Passaic, N. J.

ARMSTEAD, Frank C. (1906), 1085 E. 17th St., Brooklyn, N. Y.

BARNES, Arthur F. (Junior, 1910), Instr. in Mech. Engrg., Univ. of Pa., and *for mail*, 5229 Greenway Ave., Philadelphia, Pa.

BEECHER, J. F. (Associate, 1908), Checker, Indiana Steel Co., and *for mail*, 535 Jefferson St., Gary, Ind.

BERNA, George (1906), Modern Ice Machine Co. San Antonio, Tex.

BEVIN, Sydney (Junior, 1910), Asst. Fdy. Foreman, Mfr. Rider & Ericsson Hot-Air Pumps, Walden, Orange Co., N. Y.

BIXLER, Harry Z. (1907), Ch. Engr., Youngstown Steel Co., and *for mail*, 213 Arlington St., Youngstown, O.

BLUMGARDT, Isaac E. (Associate, 1908), Maxwell-Briscoe Motor Co., North Tarrytown, N. Y.

BRESLOVE, Joseph (Junior, 1906), Mech. Engr., Nivison-Weiskopf Co., and *for mail*, 2 Lee Court, Avondale, Cincinnati, O.

BUVINGER, George A. (1901; 1904), Designing Engr., Centrifugal Pumps, Allis-Chalmers Co., West Allis, and *for mail*, University Club, Milwaukee, Wis.

CARACRISTI, Virginius Z. (1904; 1907), Cons. Engr., Wheeling & Lake Erie R. R. Co., Massillon, O.

CARPENTER, Charles U. (1907), Pres., Herring-Hall-Marvin Safe Co., Hamilton, O.

CLANCY, Geo. W. (Associate, 1909), Pres., Globe Chem. Co., 68 Devonshire St., Boston, Mass., and *for mail*, 20 Manning Blvd., Albany, N. Y.

CLARK, W. Van Alan (Junior, 1910), Engrs'. Asst., Astoria Light, Heat & Power Co., Astoria, L. I., N. Y.

COLLINS, B. R. T. (1891; 1901), Engr., Stone & Webster Engrg. Corp., 147 Milk St., Boston, and *for mail*, 29 Oxford Rd., Newton Centre, Mass.

COLWELL, James V. V. (1903), Life Member; Mgr., N. E. Dept., Heine Safety Boiler Co., 176 Federal St., and 201 Devonshire St., Boston, Mass.

CORP, Charles I. (Junior, 1904), 504 W. Johnson St., Madison, Wis.

CORREA, William Howard (Junior, 1910), Asst. M. M., Standard Oil Co., Pratt Wks., Brooklyn, and *for mail*, 640 W. 139th St., New York, N. Y.

CROFOOT, George Emerson (Junior, 1907), Browning Engrg. Co., Cleveland, and *for mail*, 914 Mars Ave., Collinwood, O.

DAVIS, Thomas B. (1907; 1909), Forrest City, Ark.

DELANY, Chas H. (1907), 2946 Pierce St., San Francisco, Cal.

DODDS, William B. (Junior, 1907), 31 Everett St., Cambridge, Mass.

DOUGLASS, Wm. M. (1884), Treas., Globe Real Estate Co., 18 S. 6th St., Allentown, Pa.

EMSWILER, John Edward (Junior, 1908), Instr., Mech. Engrg., Univ. of Mich., New Engrg. Bldg., Ann Arbor, Mich.

FISHER, Henry Donald (Junior, 1907), Fuel Testing Co., 220 Devonshire St., Boston, Mass.

FRANKENBERG, George T. (Associate, 1907), Mech. Engr., Ralston Steel Car Co., and *for mail*, 1191 Oak St., Columbus, O.

FREEMAN, Perry John (Junior, 1908), Mech. Engrg. Dept., Univ. of Illinois, Urbana, Ill.

GARDNER, Henry (Junior, 1904), Asst. Supt. of Apprentices, N. Y. Central Lines, 1526 Grand Central Terminal, New York, N. Y.

HARDING, Adalbert (Junior, 1898), 24 Langdon St., Cambridge, Mass.

HART, Rogers Bonnell (Associate, 1907), Y. M. C. A., East Liberty, Pittsburg, Pa.

HOLBROOK, Percy (1900), V. P., Rail Joint Co., 185 Madison Ave., New York, N. Y.

HOLMES, Arthur (Junior, 1904), Asst. Engr., H. H. Franklin Mfg. Co., and *for mail*, 219 Lancaster Ave., Syracuse, N. Y.

JACOBI, Albert W. (1885), Life Member; Cons. Engr., 192 Market St., Newark, N. J.

JOHNSON, Louis L. (1908), 420 Law Bldg., Indianapolis, Ind.

JONES, John T. (1890), Iron Mountain, Mich.

JUNGHANS, Edward K. (1908), Ch. Engr., Central Mercedita, Ponce, P. R.

KATZENSTEIN, Martin L. (Junior, 1903), Mgr., Marine Dept., Internatl. Steam Pump Co., 115 Broadway, and *for mail*, 52 E. 81st St., New York, N. Y.

KENYON, Alfred Lewis (1904), 144 Edgewood Ave., Atlanta, Ga.

KESSLER, Armin Geo. (Junior, 1909), Engr. Dept., R. G. Peter's Mfg. Co., and *for mail* 159 Ransom St., Grand Rapids, Mich.

KIRCHHOFF, Charles (1882), Rhineland Court, 244 Riverside Drive, New York, N. Y.

KIRKUP, Joseph P. (Junior, 1908), Engrg. Dept., L. J. Wing Mfg. Co., 90 West St., New York, N. Y.

KNOWLES, Morris (1907), 2548 Oliver Bldg., Pittsburg, Pa.

KNOX, S. L. Griswold (1892; 1901), M. Burr, Jr. & Co., 20 Broad St., New York, N. Y.

LAFORE, John Armand (1904), Sales Mgr., D'Olier Engrg. Co., Philadelphia, and *for mail*, Cynwyd, Pa.

LAND, Frank (1900), Secy. and Treas., Land-Wharton Co., 912 Pa. Bldg., Philadelphia, and *for mail*, Montgomery Inn, Bryn Mawr, Pa.

LANE, J. S. (1882), M. E., Engineer Co., Cons. and Contr. Engrs., 50 Church St., New York, and 283 Highland Blvd., Brooklyn, N. Y.

LANGE, Heinrich Bartels (Junior, 1910), Hillcrest, Summit, N. J.

LEE, Robert E. (Junior 1907), Mech. Engr., 804 Monroe St., Ann Arbor, Mich.

LEMOINE, L. R. (Associate, 1887), 2nd V. P., U. S. Cast Iron Pipe & Fdy. Co., 1421 Chestnut St., Philadelphia, Pa.

LEMON, John C. (1902), Mech. Engr., Grand Opera House Bldg., and *for mail* 2844 Linwood Ave., Cincinnati, O.

LOCKWOOD, James Fred (1889; 1907), Mgr., Security Elev. Safety Co., 126 W. 18th St., New York, and *for mail*, 678 McDonough St., Brooklyn, N. Y.

McDEVITT, Frank J. (Junior, 1906), Elliott Co., and Liberty Mfg. Co., Pittsburg, Pa., and *for mail*, 1201 Manhattan Bldg., Chicago, Ill.

MAGIN, Frank W. (Junior, 1907), Allis-Chalmers Co., Milwaukee, Wis.

MALLORY, Charles K. (1907), Engr., Constr. and Maintenance, Solvay Process Co., and *for mail*, 1027 James St., Syracuse, N. Y.

MARSHALL, Wm. Crosby (1901; 1909), Asst. Prof. Descriptive Geom. and Drawing, 114 Winchester Hall, S. S. S., Yale Univ., and *for mail*, 137 Wall St., New Haven, Conn.

MERRILL, Albert S. (Junior, 1903), 509 High St., Easton, Pa.

MORGAN, John R. (1901), Mech. Engr., Box 268, Gary, Ind.

MOXHAM, Egbert (Junior, 1906), Mgr., Pulp Key Dept., E. I. du Pont de Nemours Co., and *for mail*, 1500 Pa. Ave., Wilmington, Del.

MUDGE, Samuel Tenney (Junior, 1910), Supt., Rogers Paper Mfg. Co., South Manchester, Conn

NAYLOR, John Samuel (1887), Prop., Peoples' Wks., Front St. and Girard Ave., and 201 West Chester Ave , Chestnut Hill, Philadelphia, Pa.

OTTO, Henry S. (Junior, 1909), Supt., Saurer Motor Trucks, 301-315 N. Halsted St., Chicago, Ill.

OVIATT, David B. (1891), Asst. Engr., Bd. of Water Supply, City of N. Y., 147 Varick St., and 172 W. 109th St., New York, N. Y.

PALMER, Cortlandt E. (1895), 137 E. 19th St., New York, N. Y.

PERCY, Earl N. (Junior, 1907), Mech. Engr., Standard Oil Co., and Transportation Club, Palace Hotel, San Francisco, Cal.

PINNER, Seymour W. (Junior, 1909), Edison Ill. Co. of Detroit, 18 Washington Ave., Detroit, Mich.

POPE, Harold L. (Junior, 1905), Mgr., Pope Mfg. Co., West Wks., Hartford, Conn.

POSSELT, Ejnar (Junior, 1907), Ch. Engr., Cement Securities Co., Denver, and *for mail*, care Colorado Portland Cement Co., Portland, Colo.

SANDO, Will J. (1899), Manager, 1908-1911; Milwaukee Club, Milwaukee, Wis.

SEARLE, Wilbur C. (Junior, 1909), Heald Mch. Co., and *for mail*, 23 Dover St., Worcester, Mass.

SHEPERDSON, John Wm. (Associate, 1908), Steam Engr., Cambria Steel Co., and *for mail*, 126 Tioga St., Westmont, Johnstown, Pa.

SLATER. Alpheus B. (1891), Slocums, R. I.

SLICHTER, Walter I. (Junior, 1902), Prof. Elec. Engrg., Columbia Univ., New York, N. Y.

SMITH, Edward Jos. (1904), 30 Church St., New York, and 1099 Gates Ave., Brooklyn, N. Y.

TAYLOR, Frank H. (1908), 44 E. 82d St., New York, N. Y.

THOMPSON, Edward P. (1884), M. E., Registered Pat. Atty. and Cons. Engr., 34 E. 32d St., New York, N. Y.

ULBRICHT, T. Carlile (Junior, 1908), Instr., Dept. of Power Engrg., Sibley College, Cornell Univ., Ithaca, N. Y.

VALENTINE, Louis Rossiter (Junior, 1907), Security Cement & Lime Co., Security, and *for mail*, 38 Wayside Ave., Hagerstown, Md.

WADLEIGH, George R. (1907), Hotel Berlin, St. Louis, Mo.

WEBSTER, Lawrence Burns (Junior, 1910), 15,440 Turlington Ave., Harvey, Ill.

WEGG, David S., Jr. (Junior, 1909), Telluride House, Ithaca, N. Y.; also 16 E. Ontario St., Chicago, Ill.

WETMORE, Charles P. (1901), 615 Merrill Bldg., and 518 Astor St., Milwaukee, Wis.

WILCOX, C. C. (Junior, 1905), Asst. to Cons. Elec. Engr., Hodenpyl, Walbridge & Co., 1004 Majestic Bldg., Detroit, Mich.

WILLIAMS, George W. (1904; 1907), 67 Stanley Ave., Hamilton, Ont., Canada.

WINGER, Stanley D. (Junior, 1904), Sales Engr., Green Engrg. Co., 39 Jackson Blvd., and 4447 Indiana Ave., Chicago, Ill.

YARYAN, Homer T. (1892), V. P., Yaryan Naval Stores Co , Gulfport, Miss.

YOUNG, E. R. (Junior, 1900), Cuyahoga Falls, O.

ZIMMERMANN, Wm. F. (1884), 2nd V. P., Pittsburgh Testing Lab., Rm. 386, 50 Church St., New York, N. Y.

NEW MEMBERS

CARBO, Luis Alberto (Junior, 1909), Ch. Engr., Guayaquil Sewer and Water Bd., P. O. Box 15, Guayaquil, Ecuador, S. A.

COBB, Stephen Prentis (Associate, 1910), Albany Southern R. R., Albany, N. Y.

FULLER, George W. (1910), Hering & Fuller, 170 Broadway, New York, N. Y.

WILSON, Robert Alexander (Junior, 1910), Carnegie Steel Co., Ohio Wks., Youngstown, O., and Constr. Engr., Snow Steam Pump Wks., Buffalo, N. Y.

PROMOTIONS

HAWLEY, Wm. Parker (1903; Associate, 1910), Instr., Mech. Drawing, Lewis Inst., Chicago, and 320 N. 64thAve., Oak Park, Ill.

DEATHS

BELSLEY, Clay, September 3, 1910.

JONES, Washington, July 30, 1910.

WHEELER, Frederick Meriam, September 15, 1910.

WILKINSON, Alfred, August 30, 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

ADDIS, Roscoe D. (Affiliate, 1908), Mgr., Gas Eng. Dept., Jas. Beggs & Co., 109 Liberty St., and *for mail*, 215 Audobon Ave., The Brighton, New York, N. Y.

CARACRISTI, Virginius Z. (1909), Mem. Am. Soc. M. E.

FISKE, Geo. Wallace (Affiliate, 1909), 1429 Polk St., Topeka, Kan.

JAMES, Frederick Conway (Affiliate, 1910), present address unknown.

JOHNSON, Louis L. (1910), Mem. Am. Soc. M. E.

MACNEILL, M. B. (Affiliate, 1909), Hyd. Engr., Watson-Stillman Co., Aldene, Union Co., and 110 Littleton Ave., Newark, N. J.

PERCY, Earl N. (1909), Mem. Am. Soc. M. E.

SMITH, Bronson H. (Affiliate, 1908), Asst. Engr., Westinghouse, Church, Kerr & Co., 10 Bridge St., New York, N. Y.

STEVENS, Henry R. (Affiliate, 1909), Cons. Engr., 4645 First Ave., N. E., Seattle, Wash.

ULBRICHT, T. C. (1908), Mem. Am. Soc. M. E.

VINCENT, Jay Carter (Affiliate, 1909), Asst. Engr., Power and Equip., Twin City Rapid Transit Co., and *for mail*, 3100 James Ave., S., Minneapolis, Minn.

NEW MEMBERS

FITCH, Charles L. (Affiliate, 1910), Engr., 253 Throop Ave., Brooklyn, N. Y.

PORTER, Harold Ernest (Affiliate, 1910), Engr., Tait Producer Co., New York, and *for mail*, 254 Decatur St., Brooklyn, N. Y.

STUDENT BRANCHES

CHANGES OF ADDRESS

ALLEN, Carlton H. (Student, 1910), Glen Park, Jefferson Co., N. Y.
BARRETT, Sampson A. (Student, 1910), 13 Monroe Pl., Brooklyn, N. Y.
BOLGIANO, J. R. (Student, 1909), Taylor Iron & Steel Co., High Bridge, N. J.
BRENEMAN, Paul E. (Student, 1910), 717 W. Poplar St., York, Pa.
BUSH, Charles A. (Student, 1910), Lexington, Neb.
BUTLER, W. C. M. (Student, 1910), Thurston Ave., Ithaca, N. Y.
BUYERS, Donald E. (Student, 1910), 1202 W. 3d St., Sterling, Ill.
CARLSON, Chas. A. (Student, 1910), 905 S. Busey Ave., Urbana, Ill.
CARNAHAN, O. A. (Student, 1909), 5523 Chancellor St., Philadelphia, Pa.
COBB, P. L. (Student, 1909), 38 Schermerhorn St., Brooklyn, N. Y.
COLEMAN, Wm. F. (Student, 1909), 4300 Park Ave., Chicago, Ill.
DEXTER, Robert L. (Student, 1910), 39 Pleasant Pl., Athol, Mass.
FRAMBACH, Frederick S. (Student, 1910), 292 Manhattan Ave., New York, N. Y.
GILBERT, F. B. (Student, 1909), 4759 Calumet Ave., Chicago, Ill.
GODFREY, Paul S. (Student, 1910), 198 E. Mil Ave., Wauwatosa, Wis.
HAM, C. W. (Student, 1910), 109 W. Buffalo St., Ithaca, N. Y.
HENWOOD, P. E. (Student, 1909), 4631 Calumet Ave., Chicago, Ill.
HUNTINGTON, C. S. (Student, 1909), 509 E. John St., Champaign, Ill.
JOHNSON, Charles A. (Student, 1910), 31 Orange St., Waltham, Mass.
JONAS, M. R. (Student, 1909), 205 Williams St., Ithaca, N. Y.
KASTLER, E. L. (Student, 1910), Baker Mfg. Co., Evansville, Wis.
KEOWN, B. L. (Student, 1909), Association Hall, Champaign, Ill.
KREIDLER, D. W. (Student, 1909), 1007 S. Wright St., Champaign, Ill.
LANGWILL, John S. (Student, 1910), 740 Langdon St., Madison, Wis.
LUND, J. C. (Student, 1909), 609 S. Coler Ave., Urbana, Ill.
MATTHEWS, Robertson (Student, 1910), 617 N. Cayuga St., Ithaca, N. Y.
MEYER, Richard C. (Student, 1909), 710 Thurston Ave., Ithaca, N. Y.
MOSCHEL, H. (Student, 1909), Republic Iron & Steel Co., Moline, Ill.
NORWOOD, C. T. (Student, 1909), 215 W. Cypress Ave., Redlands, Cal.
SMITH, Donald F. (Student, 1910), 411 Dryden Rd., Ithaca, N. Y.
SPONSEL, J. G. (Student, 1909), 307 E. Daniel St., Champaign, Ill.
VAUGHAN, L. L. (Student, 1910), Hartley Hall, Columbia Univ., New York, N. Y.
WATROUS, Russell W. (Student, 1910), 127 Dryden Rd., Ithaca, N. Y.
WESTLUND, A. F. (Student, 1909), 110 E. Green St., Champaign, Ill.

COMING MEETINGS

NOVEMBER—DECEMBER.

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

ALABAMA LIGHT AND TRACTION ASSOCIATION
November 21–23, annual convention, Anniston, Ala. Secy., Geo. S. Emery.

AMERICAN INSTITUTE OF MINING ENGINEERS
October 21–November 15, special meeting, Canal Zone, S.A. Secy., Dr. Joseph Struthers, 29 W. 39th St., New York.

AMERICAN MATHEMATICAL SOCIETY
December 28–29, annual meeting, Columbia University, New York. Secy., F. N. Cole.

AMERICAN RAILWAY ASSOCIATION
November 16, semi-annual meeting, St. Louis, Mo. Secy. W. F. Allen, 24 Park Pl., New York.

THE AMERICAN SOCIETY FOR THE ADVANCEMENT OF SCIENCE
December 27–January 3, Minneapolis and St. Paul, Minn. Secy., L. O. Howard, Smithsonian Institution Washington, D. C.

AMERICAN SOCIETY OF CHEMICAL ENGINEERS
December 8–10, Philadelphia, Pa. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN SOCIETY OF CIVIL ENGINEERS
November 2, 220 W. 57th St., New York. Papers: The Arch Principle in Engineering and Esthetic Aspects and its Application to Long Spans, by C. R. Grimm; November 16, The Failure of the Yuba River Dèbris Barrier and the Efforts made for its Maintenance, by H. H. Wadsworth. Secy., C. W. Hunt.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS
November 11, 29 W. 39th, St. New York. Paper: Interpole Synchronous Converters, by B. G. Lamme and F. D. Newbury. Secy., R. W. Pope.

AMERICAN SOCIETY OF REFRIFERATING ENGINEERS
December 5–6, annual meeting, New York. Secy., W. H. Ross, 154 Nassau St.

THE AMERICAN SOCIETY OF SWEDISH ENGINEERS
November 19, 271 Hicks St., Brooklyn, N. Y. Paper: Modern Development of Electric Transformer Design, by H. Pikler. Secy., A. Nilsson.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS
December 12–14, annual convention, New York. Secy., Percy H. Wilson, Land Title Building, Philadelphia, Pa.

ENGINEERS CLUB OF ST. LOUIS

December 7, annual meeting, St. Louis, Mo. Secy. A. S. Langsdorf, Washington University.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS

November 16–23, annual meeting, Washington, D. C. Reports: Powers, Duties and Work of State Railway Commissions, Legislation, Shippers' Claims on Common Carriers, Railway Service and Railway Accommodation, Construction and Operating Expenses of Electric Railways, Simplification of Railway Tariffs, Rates and Rate Making, Uniform Classification, Car Service and Demurrage, Railway Capitalization, Safety Appliances, Grade Crossings and Trespassing on Railroads, Railroad Taxes and Plans for Ascertaining the Fair Value of Railroad Property, Amendment of Act to Regulate Commerce, Delays Attendant upon Enforcing Orders of State Railway Commissions. Secy., Wm. H. Connolly, c/o Interstate Commerce Commission.

NATIONAL ASSOCIATION OF CEMENT USERS

December 12–23, annual convention, New York. President, Richard L. Humphrey, Harrison Building, Philadelphia, Pa.

NATIONAL COMMERCIAL GAS ASSOCIATION

December 5–13, annual convention and exhibition, Mechanics' Hall, Boston, Mass. Papers: Manufacturers' Paper; Industrial Fuel; Illumination; Commercial Man—His Opportunities and Future, Rates, Compensation of Solicitors; The Commercial Department as seen through the Eyes of a Traveling Salesman; Lighting and Fuel Maintenance; Water Heaters; Relations with Customers; Office and Accounting Methods. Secy., Louis Stotz, 29 W. 39th St., New York.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION

December 12–15 annual meeting, Racine, Wis. Secy., A. Stritmatter, Cincinnati, O.

NATIONAL MUNICIPAL LEAGUE

November 14–18, annual meeting, Buffalo, N. Y. Secy., Clinton Rogers Woodruff, North American Bldg., Philadelphia, Pa.

NATIONAL SOCIETY FOR PROMOTION OF INDUSTRIAL EDUCATION

December 1–3, annual convention. Secy., J. C. Monaghan, 20 W. 44th St., New York.

NEW JERSEY SANITARY ASSOCIATION

December 2–6, annual meeting, Lakewood, N. J. Secy., J. A. Exton, 75 Beech St., Arlington.

NEW YORK CEMENT SHOW

December 14–20, first annual convention, Madison Square Garden, New York. Under the management of the Cement Producers Company, 115 Adams St., Chicago, Ill.

NORTHERN RAILWAY CLUB

November 26, Duluth, Minn. Secy., C. L. Kennedy, C. M. & St. P. Ry., 401 West Superior St.

OHIO SOCIETY OF MECHANICAL, ELECTRICAL AND STEAM ENGINEERS

November 18–19, annual meeting, Springfield, O. Secy., F. E. Sanborn, Ohio State University, Columbus.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
November			
2	Wireless Institute	S. L. Williams	7.30 p.m.
3	Blue Room Engineering Society	W. D. Sprague	8.00 p.m.
9	American Institute Mechanical Engineers	C. W. Rice	8.15 p.m.
10	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
11	American Institute of Electrical Engineers	R. W. Pope	8.00 p.m.
15	New York Telephone Society	T. H. Lawrence	8.00 p.m.
17–18	Society of Naval Architects and Marine Engineers	W. J. Baxter	All day
18	New York Railroad Club	H. D. Vought	8.15 p.m.
23	Municipal Engineers of New York	C. D. Pollock	8.15 p.m.
December			
1	Blue Room Engineering Society	W. D. Sprague	8.15 p.m.
6, 7, 8, 9	American Society Mechanical Engineers	C. W. Rice	All day
7	Wireless Institute	S. L. Williams	8.00 p.m.
8	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
9	American Society Electrical Engineers	R. W. Pope	8.00 p.m.
16	New York Railroad Club	H. D. Vought	8.15 p.m.
20	New York Telephone Society	T. H. Lawrence	8.15 p.m.
28	Municipal Engineers of New York	C. D. Pollock	8.15 p.m

CURRENT BOOKS

The Construction of Graphical Charts. By John B. Peddle. *New York, McGraw-Hill Book Co., 1910.* Cloth, 8vo, 109 pp., illustrated. Price, $1.50.

Contents: Charts Plotted on Rectangular Co-ordinates; The Alinement Chart; Alinement Charts for More than Three Variables; The Hexagonal Index Charts; Proportional Chart; Empirical Equations; Stereographic Charts and Solid Models.

Electric Motors, Continuous, Polyphase and Single-Phase Motors. Their Theory and Construction. By Henry M. Hobart. Second edition, revised and enlarged. *New York, The Macmillan Co., 1910.* Cloth, 8vo, 748 pp., 798 illustrations. Price, $5.50.

Contents: Part I. Continuous Motors: Introductory; General Discussion of Continuous Motors; Data for Motor Designing; Types of Armature Windings; Compound-Wound, Series, and Shunt Motors; Hopkinson Method of Motor Testing; Commutator Design; Comparative Designs for 35-h.p. Motor; Examples of Shunt Motor Designs by Different Manufacturers; Examples of Designs of Compound Motors; Interpole Motors; Variable-Speed Motors; Traction Motors; Part II. Polyphase Motors: Desirability of Using Polyphase Electricity; Methods of Starting Induction Motors; Comparisons Between Induction and Continuous Motors; The Design of Three-Phase Induction Motors; the Circle Diagram and its Practical Applications; The Torque of Induction Motors; The Circle Coefficient; Heating of Induction Motors; Calculations of I^2 R Loss in Squirrel-Cage Induction Motor Design; Examples of Three-Phase, Slip-Ring Induction Motors of Small Outputs; Examples of Three-Phase Induction Motor Designs Employing Wound Rotors, Having Medium Outputs; Examples of Three-Phase Induction Motor Designs, Employing Wound Rotors, Having Large Outputs; The Hunt Squirrel Cage; Variable-Speed Polyphase Motor; The Design of Small Motors for Manufacture in Large Quantities; Cost and Weight Coefficients of Induction Motors; Part III. Single-Phase Motors: Introductory; The Single-Phase Induction Motor without a Commutator; The Single-Phase Series Motor; The Repulsion Motor; The Compensated Repulsion Motor; Other Single-Phase Railway Motors; The Déri Repulsion Motor; Creedy's Design of an Atkinson Repulsion Motor; The Wagner Single-Phase Commutator Motor; The Schüler Motor; Variable-Pole Repulsion Induction Single-Phase Commutator Motor; Shunt Single-Phase Commutator Motor.

The Mechanical Engineers Pocket-Book. A Reference-Book of Rules, Tables, Data, and Formulae, for the Use of Engineers, Mechanics, and Students. By William Kent. 8th ed., rewritten. *New York, John Wiley & Sons, 1910.* Morocco, pocket-book size, 1461 pp. Price, $5 net.

Contents: Mathematics: Arithemetic, Weights and Measures, Algebra, Mensuration, Plane Surfaces, Mensuration, Solid Bodies, Plane Trigonometry, Analytical Geometry, Differential Calculus, Slide Rule, Logarithmic Ruled Paper, Mathematical Tables, Materials, Miscellaneous Materials, Strength of Materials, Alloys, Ropes and Cables, Springs, Riveted Joints, Iron and Steel, Steel; Mechanics; Elements, Stresses in Framed Structures; Heat; Physical Properties of Gases; Air: Flow of Air, Wind, Compressed Air, Fans and Blowers; Heating and Ventilation; Water: Hydraulics, Flow of Water, Water-Power, Water Wheels, Turbine Wheels, The Power of Ocean Waves, Pumps, Hydraulic Pressure Transmission; Fuel: Liquid Fuel, Fuel Gas, Acetylene and Calcium Carbide, Illuminating Gas; Steam: Flow of Steam, Steam-Pipes; The Steam Boiler; Strength of Steam-Boilers; Boiler Attachments, Furnaces etc., Safety-Valves, The Injector, Feed-Water Heaters, Steam

Separators, Determination of Moisture in Steam, Chimneys; The Steam Engine: Compound Engines, Steam-Engine Economy, Dimensions of Parts of Engines, Fly-Wheels, Slide-Valve, Governors, Condensers, Air-Pumps, Circulating-Pumps, etc., Rotary Steam Engines, Steam Turbines, Naphtha Engines, Hot-Air Engines, Internal Combustion Engines; Locomotives; Shafting; Pulleys; Belting; Gearing: Forms of Teeth, Strength of Gear Teeth; Hoisting and Conveying, Cranes, Coal-Handling Machinery, Wire-Rope Haulage; Wire-Rope Transmission; Rope Driving; Friction and Lubrication: Friction Brakes and Friction Clutches, Lubrication; The Foundry; The Machine Shop: Abrasive Processes, Various Tools and Processes; Dynamometers; Ice Making or Refrigerating Machines; Marine Engineering: Screw-Propeller, Marine Practice, Paddle-Wheel, Jet Propulsion; Construction of Buildings: Foundations, Masonry, Beams and Girders, Walls, Floors, Columns and Posts; Electrical Engineering: Electrical Resistance, Direct Electric Currents, Electric Transmission, Direct-Currents, Electric Railways, Electric Lighting, Illumination, Electric Batteries, Magnetic Circuit, Dynamo-Electric Machines, Alternating Currents, Alternating Current Circuits, Transformers, Converters, etc., Electric Motors, Alternating Current Motors, Sizes of Electric Generators and Motors.

RUSSIAN TURKESTAN AND ITS PRODUCTS. By N. J. Malahowski. *St. Petersburg, 1910.*

STANDARD HANDBOOK FOR ELECTRICAL ENGINEERS. Written and compiled by a staff of specialists. 3d ed., revised and enlarged. *New York, McGraw-Hill Book Co., 1910.* Morocco, pocket-book size, 1497 pp., reference tables. Price, $4 net.

Contents: Units; Electric, magnetic and dielectric currents; Measurements and Measuring Apparatus; Properties of Materials; Magnets, Restorers, Condensers and Reactors; Transformers and Converters; Electric Generators; Electric Motors; Batteries; Central Stations; Transmission and Distribution; Illumination; Electric Traction; Electrochemistry; Telephony; Telegraphy; Miscellaneous Applications; Wiring; Standardization Rules; Tables and Statistics.

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Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	A. Mac Arthur	A. Wegner
Univ. of Missouri, Columbia, Mo.	December 7	H. Wade Hibbard	R. V. Aycock	Osmer Edgar
Univ. of Nebraska, Lincoln, Neb.	December 7	C. R. Richards	W. J. Wholenberg	W. H. Burleigh
	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams
Yale University, New Haven, Conn.	October 11			W. Roy Manny

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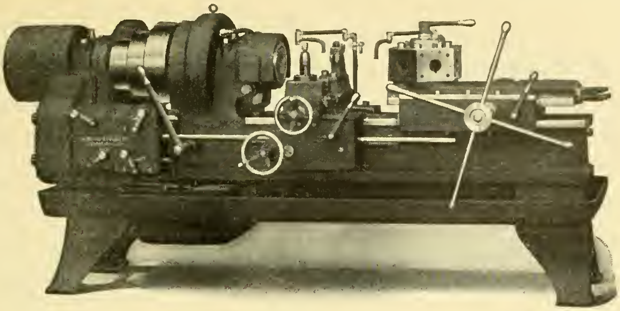

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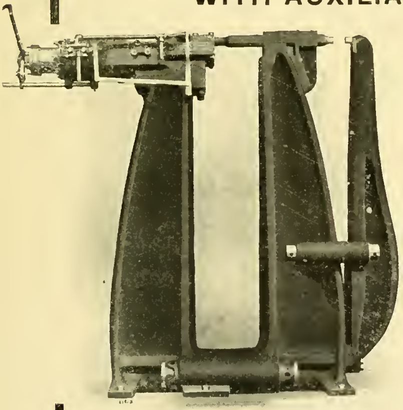

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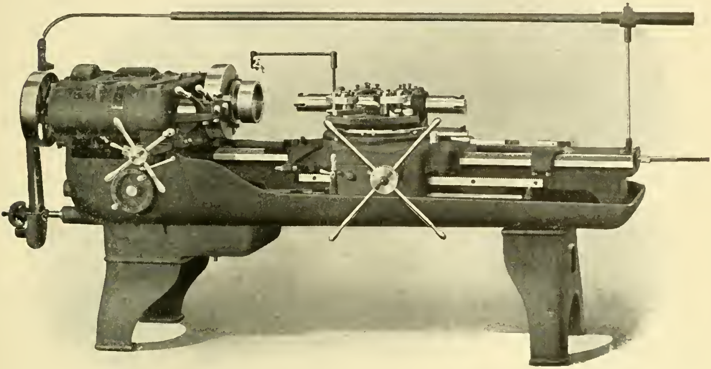

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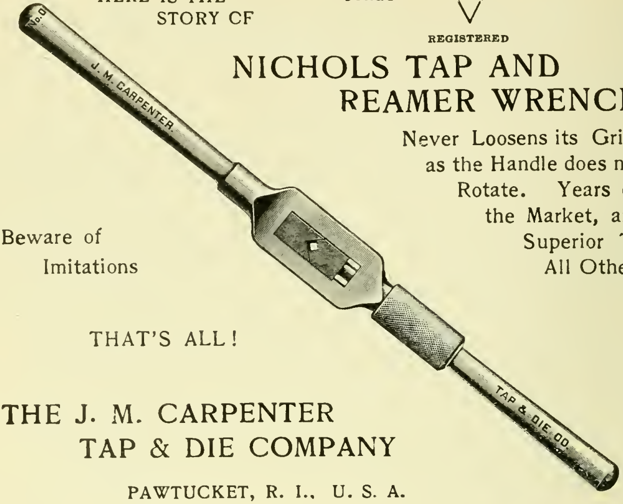

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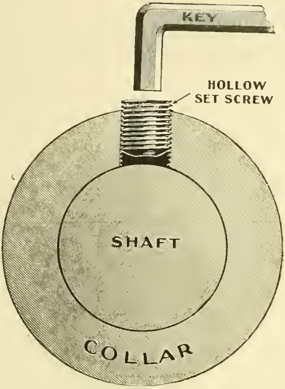

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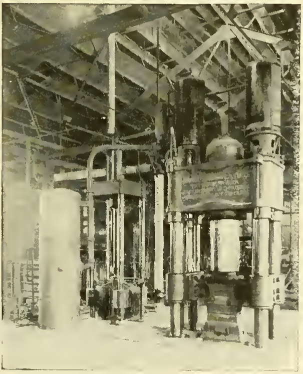

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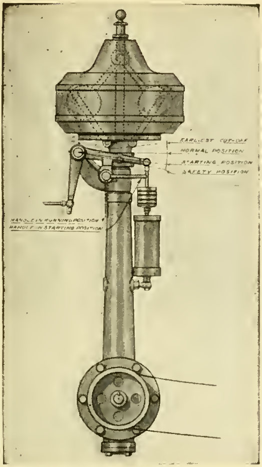

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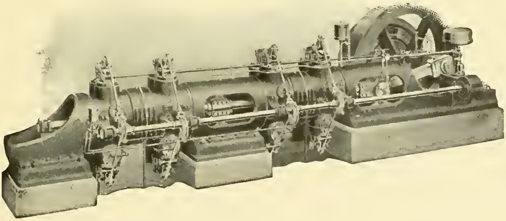

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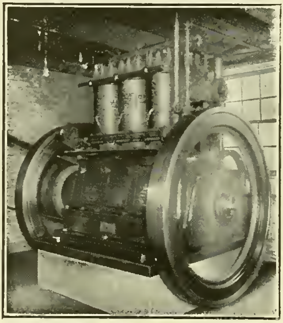

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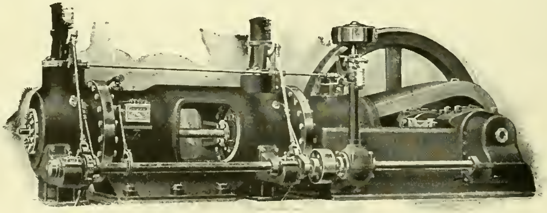

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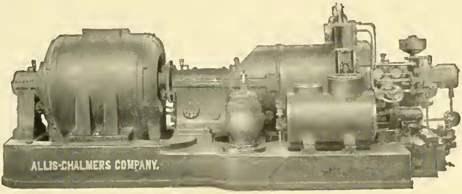

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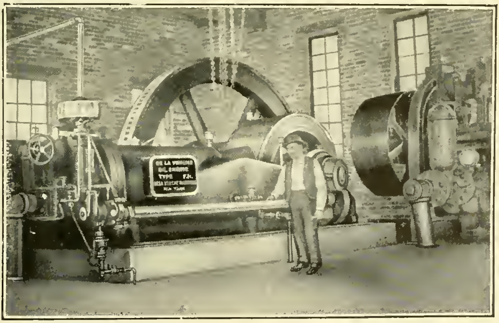

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Valves that have been opened and closed *three thousand times* without showing sign of wear or leak.

Valves that are opened and closed *thirty to forty times per day* for alternate supply of *cold water* and *live steam;* at this rate *three hundred and thirteen days per year*, without leakage or repairs from year to year.

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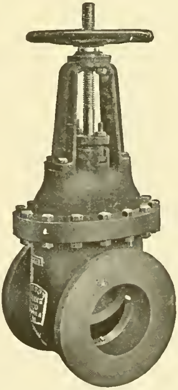

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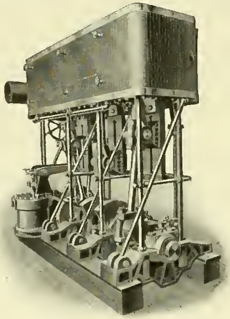

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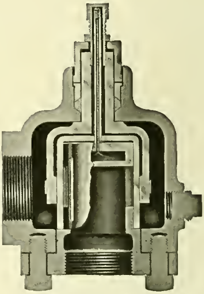

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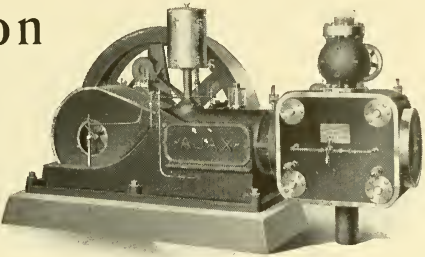

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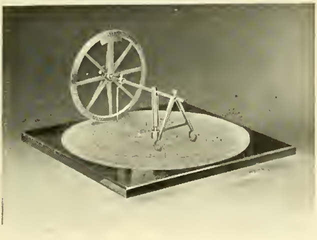

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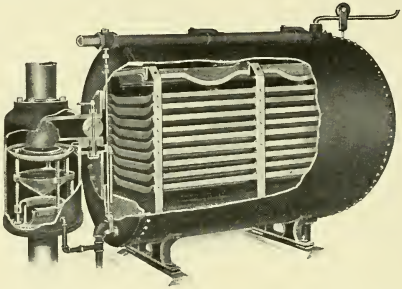

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Exhaust Steam Feed-Water Heaters, Live Steam Feed-Water Purifiers, Steam and Oil Separators, Exhaust Heads

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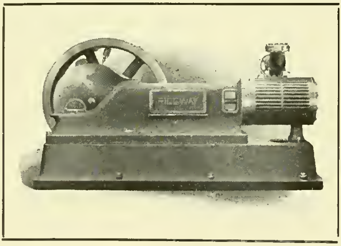

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Successors to
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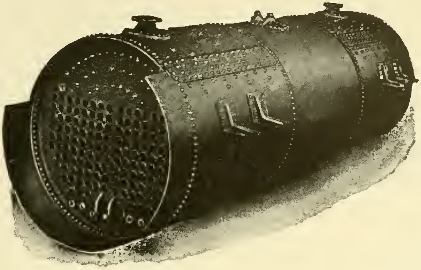

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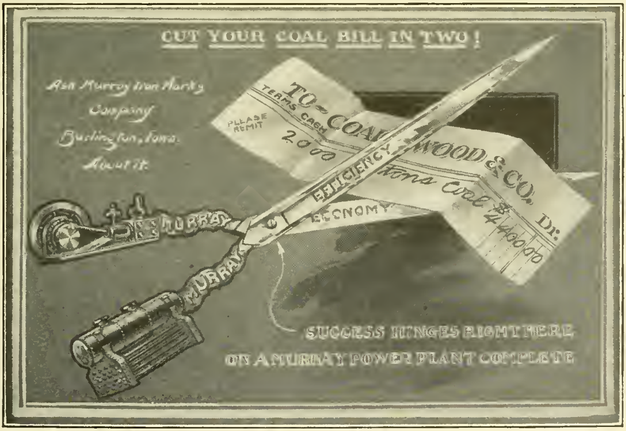
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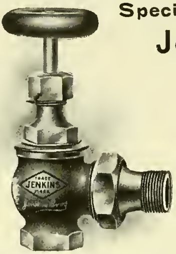

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Specifying these valves, and then insisting that your contractor installs just what is called for, will secure for you the heaviest radiator valves made. Highest grade metal and workmanship. Full opening. All parts renewable. Can be packed under pressure.

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Reduces friction, saves wear, prevents seizing and scoring.

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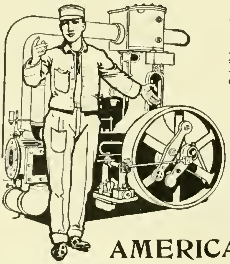

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If you are paying more than this for lighting and power current you are throwing good money away,—might just as well get a K.W. hr. for two cents and put the difference in your pocket. Hundreds of plants are already running as economically as this by using

AMERICAN BALL ANGLE COMPOUND DIRECT CONNECTED UNITS

The Angle Compound Unit is built especially for isolated plant service. It has superior steam economy, gets twice as much power on the same floor space as a simple engine, needs very little attention (as it has no complicated valve gears and automatic lubrication), sets up absolutely no vibrations, and is therefore suitable for use in apartment houses, hospitals, hotels, etc. Write for catalog.

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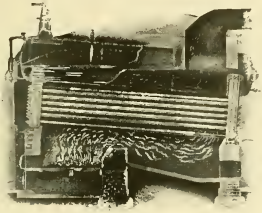

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HEINE WATER TUBE **BOILERS**

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In units of from 50 to 600 H. P.

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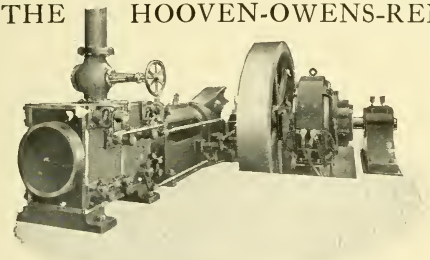

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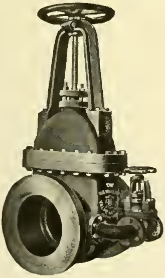

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We concentrate our entire attention on valves and hydrants and do not have a line of miscellaneous sundries such as fittings, boiler trimmings, etc., to divide our interests. Thus we can give valves particular attention.

The result of this concentrated effort is shown in Kennedy Valves—it shows in their design, workmanship and finish.

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THE KENNEDY VALVE MFG. CO.

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(PATENTED)

TURN WASTED POWER INTO PRODUCT

2400 more picks a minute are being obtained by equipping one Loom driving pulley.

1044 more R. P. M. are being obtained by the equipment of one Winding Machine Clutch.

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500 more spindle-hours are being obtained by equipping one Mule Friction.

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400 more R. P. M. are being obtained by the equipment of one Spinning Frame Pulley.

In each of these cases and thousands of others the increase in product very quickly paid for the Cork Insert installation and thereafter the gain is clear profit.

How about Friction Losses in your plant

Will you try a
Cork Insert Pulley
Cork Insert Clutch
Cork Insert Friction

NATIONAL BRAKE & CLUTCH COMPANY

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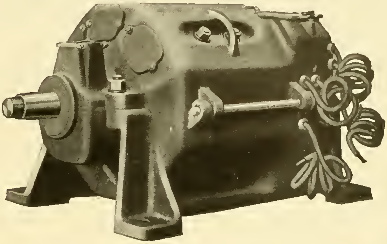
SECTION 3

Electrical Equipment

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
Directory of Mechanical Equipment - - - Section 6

Type "MT" Direct Current Mill Motors



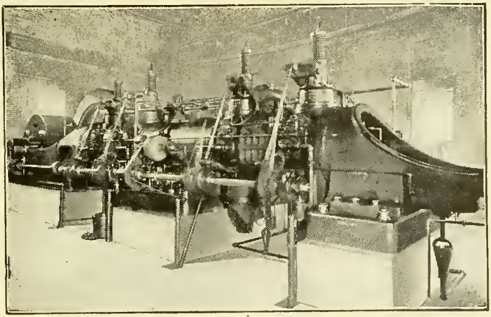
Two important points commending Type "MT" Motors for heavy mill service are:

1st. The design of the frame of each Westinghouse Mill-Type Motor, from 5 to 150 horse power, is identical, and of the same heavy, massive construction.

2nd. The steel cut gears for all sizes of motors have large pitch, liberal face, and are of exceptionally heavy design.

See Circular No. 1144

Westinghouse Electric & Manufacturing Co., Pittsburg, Pa.
Sales Offices in all Large Cities



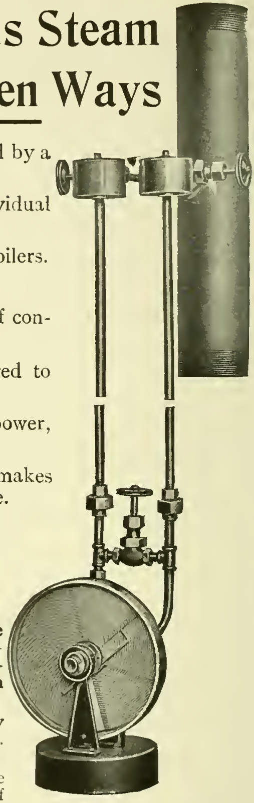
One of the 500 KW. Westinghouse Gas Engine Generating Units
Warren and Jamestown Electric Railway

A peculiar advantage of a Westinghouse Gas Power Plant is, that in cold weather, when the peak demand commonly occurs, the engine is supplied with cold gas, and therefore furnishes its maximum power.

During, and subseqent, to last winters heavy snow storm in the vicinity of Warren, Pa., all roads, including steam and electric lines, were forced to abandon service with the exception of the Warren & Jamestown Electric Railway. This road is served by a generating station at Stoneham, Pa., which includes three Westinghouse horizontal single tandem gas engines, two 500 KW. and one 750 K.W. Capacity. The motor equipment of the cars not only increased in capacity due to better cooling, but the gas engines likewise increase in capacity owing to the cold weather, by gas going over to the engines at a lower temperature, effecting better cylinder filling and consequently producing more power.

THE WESTINGHOUSE MACHINE COMPANY
PITTSBURG, PA.

The GE Flow Meter Aids Steam Plant Operation in Seven Ways



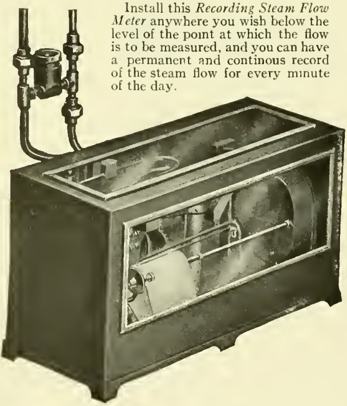
1. It records the total amount of steam generated by a battery of boilers.
2. It enables equalization of the load on individual boilers.
3. It detects internal leaks and deterioration of boilers.
4. It determines the efficiency of stoking.
5. It locates losses between boilers and points of consumption.
6. It records the total amount of steam delivered to any department.
7. It records the amount of steam sold for power, heating or manufacturing purposes.

Any one of the many uses of the G-E Flow Meter makes it worth while to equip your plant with this device.

Simple in Operation: Thoroughly Practical

The G-E Flow Meter operates on the well-known principle of the Pitot tube. The pressure due to velocity head is measured, and in this way the exact rate of steam flow is determined. No steam enters the meter. There can be no friction error—there are no parts to wear or get out of adjustment.

A G-E Flow-Meter can be attached to any steam pipe by simply tapping a hole and inserting the proper sized plug. One meter can be used for any diameter of pipe.



Install this *Recording Steam Flow Meter* anywhere you wish below the level of the point at which the flow is to be measured, and you can have a permanent and continous record of the steam flow for every minute of the day.

A complete description of the G-E Flow Meter is contained in Bulletin 4720-C. A postal brings it to you.

The portability of the *Indicating Steam Flow Meter* makes it serviceable for locating leaks or taking instantaneous readings anywhere about the plant. Weight 25 lbs.

For Pulsating Flow

Such as occur in operating reciprocating engines, pumps, etc., receiver capacity sufficient to produce continuous flow at the point of installation is necessary unless the meter can be recalibrated after it is installed. To recalibrate the meter for this condition, a water rate test must be run on the unit consuming the steam. We will be pleased to advise you if the G-E Flow Meter can be adapted to your particular condition.

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Largest Electrical Manufacturer in the World
Sales Offices in all Large Cities

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Require no preliminary period of grooming and experimentation.

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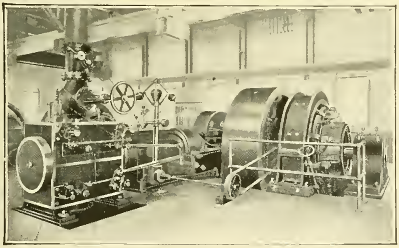
DIRECT CURRENT **FOR LIGHT AND POWER**

¼ Kw. to 1000 Kw.



Sprague Electric 400 Kw. Generator
In Plant of Standard Bleachery Co., Carlton Hill, N. J.

Reduce expense, are of high efficiency, best materials and workmanship.

Why not send for BULLETIN 11060?

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Power Transmission

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Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
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THE OVERHEAD WAY

WITH an Electric Triplex Hoist swung from a trolley one man can handle more coal and ashes in a day than by any other method.

A push on the switch enables him to lift a load that he never could handle by hand.

He can then push it to its destination—something he also could never do with the same load on a truck or barrow.

The Electric Triplex Hoist has effected the greatest revolution in load lifting and moving since the wheel was first invented.

We have a book about Electric Hoists which we should like very much to send you. All we ask is your name on a post card.

Chain Blocks
- **4 Styles:** Differential, Duplex, Triplex, Electric.
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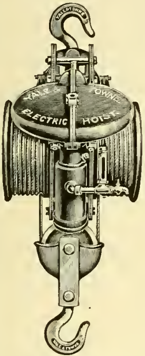
- **300 Active Stocks** ready for instant call all over the United States.



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ALL TYPES

FOR EVERY KIND OF SERVICE

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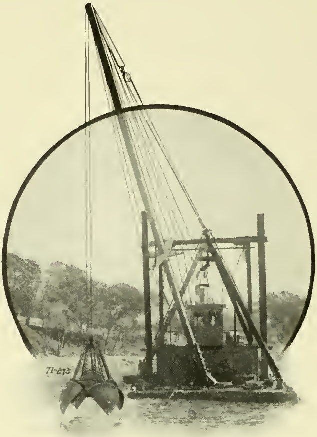

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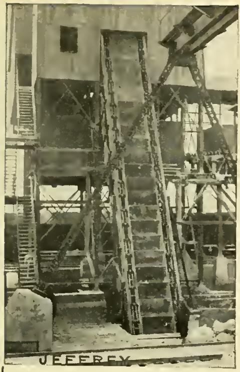

Jeffrey Elevators

are adapted for all practicable requirements.

This Jeffrey Bucket Elevator is 95 ft. high, capacity 750 tons per hour, handling crushed stone.

Write today for booklet K34, it describes styles for various classes of work.

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Conveyor Belt User

Have you had trouble with the Edge of Your Belt?
Does it come loose, peel, break off, or wear away?
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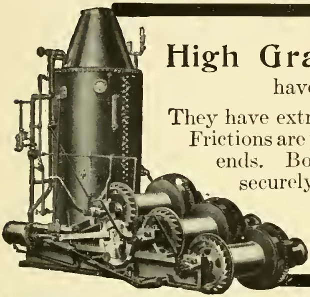

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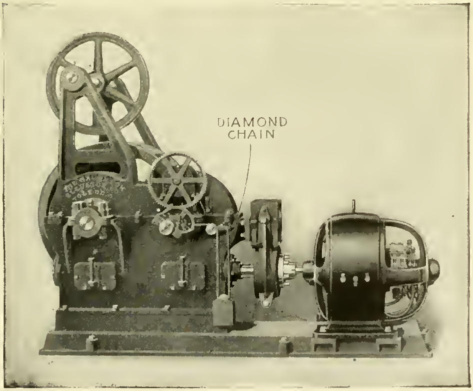

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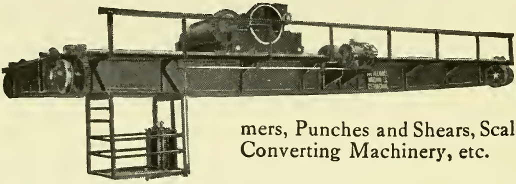

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SECTION 5

Engineering Miscellany

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
Directory of Mechanical Equipment - - - Section 6

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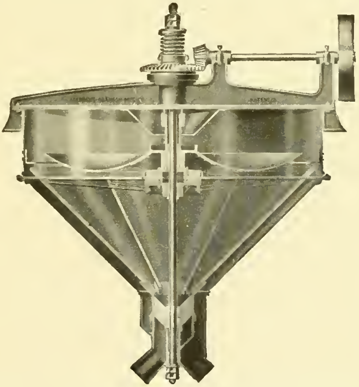

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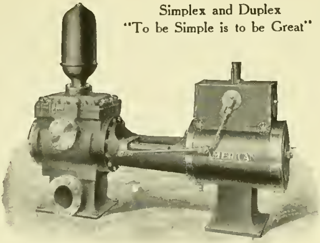

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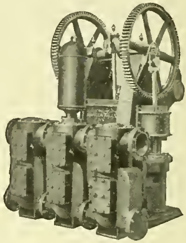

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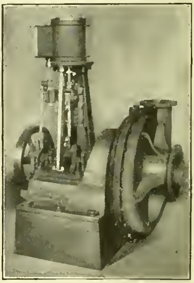

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ADVERTISING SUPPLEMENT

SECTION 6

DIRECTORY
OF
MECHANICAL EQUIPMENT

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ALPHABETICAL LIST OF ADVERTISERS

Page
Alliance Machine Co 28, 46
Allis-Chalmers Co...9, 21, 36, 42, 43
Almy Water Tube Boiler Co...... 34
American Engine Co..........16, 34
American Injector Co............ 37
American Pulley Co.............. 45
American Steam Gauge & Valve Mfg. Co...................... 37
American Steam Pump Co.....30, 43
Arnold Co., The................. 50
Ashton Valve Co................ 37
Atlantic Hydraulic Machinery Co. 43

Babcock & Wilcox Co.........16, 34
Baldwin, Bert. L................ 50
Ball Engine Co.................. 34
Blaisdell Machinery Co.......... 44
Bridgeport Brass Co..........10, 37
Bristol Co..................13, 38
Broderick & Bascom Rope Co.... 46
Brown Hoisting Mchy. Co...... 46
Bruce-Macbeth Engine Co...... 36
Buckeye Engine Co...........7, 34
Builders Iron Foundry........30, 43
Bulkley, Henry W.............. 38
Butterfield & Co................ 31

Caldwell & Son Co., H. W....... 46
Carborundum Co................ 31
Carpenter Tap & Die Co., J. M..4, 31
Chapman Valve Mfg. Co........ 38
Chicago Pneumatic Tool Co..... 44
Cincinnati Gear Cutting Machine Co............................ 31
Cincinnati Shaper Co............ 31
Clarkson School of Technology... 50
Clyde Iron Works 27, 46
Conard, William R............... 50
Crosby Steam Gage & Valve Co.. 38

Dallett Co., Thos H............ 45
Davidson Co., M. T............ 43
Dean, F. W.................... 50
Dearborn Drug & Chemical Wks. 38
De La Vergne Mach. Co.......9, 36
Diamond Chain & Mfg. Co...27, 45
Dixon Crucible Co., Joseph..16, 38
Dodge, Day & Zimmermann 49
Dodge Mfg. Co.................. 45
Dodge Co., J. M............... 47

Page
Eastern Machinery Co.......... 47
Engineer Co.................... 38
Engineering Schools & Colleges.. 50
Erie City Iron Works............ 34
Exeter Machine Works.......... 41

Fellows Gear Shaper Co......... 31
Franklin Boiler Works Co....17, 34

Garvin Machine Co............. 31
Gas Engine & Power Co., and Chas. L. Seabury & Co., Cons.12, 36
General Electric Co..........20, 42
Goodrich Co., B. F...........25, 47
Goulds Mfg. Co..............30, 44
Goyne Steam Pump Co.......... 44
Grant Mfg. & Machine Co...... 32

Hammacher Schlemmer & Co...5, 32
Harrington & King Perforating Co............................ 49
Harrisburg Foundry & Machine Works......................... 35
Harrison Safety Boiler Works.... 38
Heine Safety Boiler Co........17, 35
Herrick, J. A.................. 50
Hewes & Phillips Iron Works..13, 35
Hill Clutch Co.................. 45
Holyoke Machine Co.......... 44
Homestead Valve Mfg. Co...... 39
Hooven, Owens, Rentschler Co.17, 35
Hoppes Mfg. Co..............14, 39
Hughson Steam Specialty Co.. 39

Ide & Sons, A. L............... 35

Jakobsson, Herman.............. 50
Jeffrey Mfg. Co..............25, 47
Jenkins Bros.................16, 39
Jones & Lamson Machine Co. 2, 3, 32

Keasbey Co., Robt. A............ 39
Kennedy Valve Mfg. Co......17, 39
King Machine Tool Co.......... 32

Laclede-Christy Clay Products Co............................ 39
Le Blond Machine Tool Co., R. K.. 32
Lidgerwood Mfg. Co............ 47

Page
Link-Belt Co 47
Ludlow Valve Mfg. Co........ 39

McCord & Co.................. 40
Main, Chas. T.................. 50
Manning, Maxwell & Moore.... 6, 32
Mead-Morrison Mfg. Co......24, 47
Mietz Iron Foundry & Machine Works, August................ 37
Model Stoker Co. 40
Monarch Valve & Mfg. Co...... 40
Morehead Mfg. Co............... 40
Morgan Engineering Co.......... 47
Morris Machine Works........30, 44
Murray Iron Works Co........15, 35

National Brake & Clutch Co..18, 45
National Machine Co............ 32
National Machinery Co........6, 32
National Meter Co.............8, 37
Nelson Valve Co..............11, 40
New Process Raw Hide Co... .. 33
New York University School of Applied Science............... 50
Nicholson & Co., W. H......... 40
Niles-Bement-Pond Co..........1, 33
Northern Engineering Works..28, 48

Ohio Injector Co................ 40
Oneida Steel Pulley Co.......... 45
Otis Elevator Co.............23, 48

Paxson Co., J. W............... 49
Peterson, J. Wm 50
Polytechnic Institute of Brooklyn 50
Power Plant Specialty Co...... 40
Power Specialty Co............. 41
Professional Cards.............. 50
Providence Engineering Works.. 35

Quimby, Wm. E................ 44

Reedy Co., H. J...............27, 48
Reliance Electric & Engrg. Co.... 42

Page
Rensselaer Polytechnic Institute. 50
Ridgway Dynamo & Engine Co. 14, 35
Robb-Mumford Boiler Co.... 15, 36
Rockwood Manufacturing Co.... 46
Roebling's Sons Co., John A..26, 48
Roots Co., P. H. & F. M......... 42
Ruggles-Coles Engineering Co.. 42
Russell, Burdsall & Ward Bolt and Nut Co...................6, 33

Scaife & Sons Co., Wm. B....... 41
Shaw Electric Crane Co........ 48
Simmons Co., John..........12, 41
Sprague Electric Co..........21, 42
Standard Roller Bearing Co...28, 49
Standard Tool Co.............. 6, 33
Stephens-Adamson Mfg. Co.. 29, 48
Struthers-Wells Co.............8, 37
Sturtevant Co., B. F........... 42

Tight Joint Co................. 41
Tufts College 50

United Engineering & Foundry Co..........................5, 33

Wagner Electric Mfg. Co........ 43
Waltham Machine Works...... 33
Warner & Swasey Co.........1, 33
Webster Mfg. Co.............. 48
Westinghouse Electric & Mfg. Co........................19, 43
Westinghouse Machine Co....19, 36
Wheeler Condenser & Engrg. Co.. 41
Wheeler Mfg. Co., C. H........... 41
Whiting Foundry Equipment Co. 28, 49
Wiley & Russell Mfg Co........ 33
Williams & Wilkins Co........... 26
Wisconsin Engine Co..........7, 36
Wood's Sons Co., T. B........... 46

Yale & Towne Mfg. Co........23, 48

LIBRARY

THE
JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

CONTAINING
THE PROCEEDINGS

DECEMBER 1910

ANNUAL MEETING, NEW YORK, DECEMBER 6-9;
ST. LOUIS MEETING, DECEMBER 10;
BOSTON MEETING, DECEMBER 16.

DECEMBER 1910 VOL. 32 No. 12

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CONTENTS

SOCIETY AFFAIRS

Committee on Meetings in New York (3). Annual Meeting (4). Coming Meetings: St. Louis (9), Boston (9). Reports of Meetings: New York (9), Boston (10), St. Louis (11). Meeting of the Council (12). Student Branches (15). Necrology (17). Reports of Standing Committees to the Council (20).

PAPERS

Modern Shoe Manufacture, M. B. Kaven and J. B. Hadaway...... 1961
Operating Conditions of Passenger Elevators, R. P. Bolton....... 1983
A New Theory of Belt Driving, Selby Haar........................ 1997
Notes on the Value of Napier's Coefficient with Superheated Steam, Isaac Harter, Jr.. 2017
Combustion and Boiler Efficiency, Edw. A. Uehling............... 2023
Notes on a Heavy-Duty Gas Producer, Nisbet Latta 2079
Test of a 10,000-kw. Steam Turbine, Sam. L. Naphtaly............ 2089
Test of a 9000-kw. Turbo-Generator Set, F. H. Varney............ 2105
The Field for Grinding, C. H. Norton........................... 2113
Precision Grinding, W. A. Viall................................ 2127
Modern Grinding Methods, B. M. W. Hanson...................... 2139

GENERAL NOTES.. 2151
PERSONALS.. 2156
ACCESSIONS TO THE LIBRARY...................................... 2159
EMPLOYMENT BULLETIN.. 2164
CHANGES OF MEMBERSHIP.. 2167
COMING MEETINGS.. 2176
CURRENT BOOKS.. 2179
OFFICERS AND COMMITTEES.. 2180

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The Society as a body is not responsible for the statements of facts of pinions advanced in papers or discussions. C55

THE JOURNAL
OF
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

VOL. 32 DECEMBER 1910 NUMBER 12

COMMITTEE ON MEETINGS OF THE SOCIETY IN NEW YORK

At a meeting of the membership held on October 31, nominations were made and approved by the Committee on Meetings for a Committee on Meetings of the Society in New York, similar to the committees in Boston, St. Louis and San Francisco. The committee chosen consists of Prof. Walter Rautenstrauch, Chairman, Frederick A. Waldron, Treasurer, Fred. H. Colvin, Edward Van Winkle and Roy V. Wright. This is one of the most important developments of the year, as it places for the first time in the history of the Society all the meetings on the same basis. This committee will also form the nucleus of the committee to conduct the social features of the Annual Meeting. The duties of the committee in New York will not in any way overlap those of the Committee on Meetings of the Society, which will have jurisdiction, as formerly, over all the meetings in general and of the Annual and Spring meetings in particular.

THE ANNUAL MEETING

The Thirty-second Annual Meeting of the Society will be held in the Engineering Societies Building, 29 West 39th Street, New York, December 6–9, 1910.

A professional program with papers of unusual variety and merit has been arranged by the Meetings Committee, Willis E. Hall, Chairman, and provides for five sessions, to occupy the morning and afternoon of both Wednesday and Thursday, leaving Friday free for excursions or other entertainment. At the Wednesday morning session, following the presentation of reports and other business, there will be an account of the Joint Meeting in England by the Secretary; and also a paper on the Transmission of Heat in Surface Condensation by George A. Orrok. On Wednesday afternoon a session on Steam Engineering will be held; and on Thursday there will be a session in the morning on miscellaneous topics, with simultaneous meetings in the afternoon, one on machine shop topics, and the other that of the Gas Power Section. Luncheon will be served on both Wednesday and Thursday to members and guests.

ENTERTAINMENT

The entertainment features will be in charge this year of the Committee on Meetings of the Society in New York, Walter Rautenstrauch, Chairman, Frederick A. Waldron, Treasurer, F. H. Colvin, Edward Van Winkle and Roydon V. Wright, assisted by sub-committees. A number of excursions have been planned for Friday morning and afternoon, including the New York Public Library, not yet open to the general public, Nelson Goodyear, Inc., with an exhibit of autogenous welding, Pond Machine Tool Company, Thompson-Lovelace Aeroplane Company, Robins Dry Dock, New York Telephone Company's Exchange, and the Navy Yard in Brooklyn. There will also be opportunities throughout the convention to visit the Metropolitan Building, the Hudson and Manhattan Power House, the Interboro Power House, the Hill Publishing Company, New York Edison Company's waterside power plant, the Franco-American Soup Company, and the Sims Magneto Company.

A Ladies' Reception Committee, under the chairmanship of Mrs. Herbert Gray Torrey, will arrange for the entertainment of the guests of the membership in a manner similar to that of previous years. Tea will be served on Tuesday, Wednesday and Thursday afternoons in the Ladies' Headquarters in the rooms of the Society, and various trips to points of interest, including shops and hotels, will be made under competent guides.

RECEPTION AND EVENING MEETINGS

The opening session on Tuesday evening will be the occasion of the annual address of the President, and of the report of the Tellers of Election of Officers. This will be followed by a reception by the President and President-elect in the rooms of the Society. On Wednesday evening there will be a reunion of the membership at the Hotel Astor, with dancing and refreshments. Boxes will be available for those who do not desire to participate in the dancing.

Mr. and Mrs. Westinghouse will receive the members and guests at the Hotel St. Regis from four to six o'clock on Thursday afternoon.

The lecture on Thursday evening, by Dr. Georg Kerschensteiner on Industrial Continuation Schools of Munich, will be one of unusual interest because of Dr. Kerschensteiner's wide reputation as an educator and brilliant lecturer and his own interest in the important subject of the training of workmen. This lecture, although it appears on the program of the Annual Meeting, is one arranged through the courtesy of the National Society for the Promotion of Industrial Education, the Society, together with the American Institute of Electrical Engineers and the American Institute of Mining Engineers, having been invited by the National Society for the Promotion of Industrial Education to act as joint hosts on this occasion.

HEADQUARTERS

The headquarters will be established in the foyer on the first floor of the Engineering Societies' Building. Members and guests are requested to register immediately upon their arrival and receive a badge and program. Railroad certificates should be presented at that time for validation. A writing room will be provided on the first floor opposite the entrance fully equipped for the use of members. There is also a telephone exchange with several booths on the first floor adjoining the elevators, providing ample facilities for quick service.

MEMBERS REGISTER

Two editions of the printed Members Register will be issued. The first will include the names of those registered before 9 p.m. Tuesday, and will be distributed at the morning session on Wednesday. The second edition will contain the names of those registered before 10 p.m. on Wednesday. It will be distributed at the morning session on Thursday.

RAILROAD TRANSPORTATION

Arrangements for hotel, transportation and Pullman car accommodations should be made personally.

For members and guests attending the Annual Meeting in New York, December 6-9, 1910, the special rate of a fare and three-fifths for the round trip, on the certificate plan, is granted when the regular fare is 75 cents and upwards, from territory specified below.

a Buy your ticket at full fare for the going journey, between December 2 and 8 inclusive, and get a certificate, *not a receipt*, securing these at least half an hour before the departure of the train.

b Certificates are not kept at all stations. If your station agent has not certificates and through tickets, he will tell you the nearest station where they can be obtained. Buy a local ticket to that point and there get your certificate and through ticket.

c On arrival at the meeting, present your certificate to S. Edgar Whitaker, office manager, at the Headquarters. A fee of 25 cents will be collected for each certificate validated. No certificate can be validated after December 9.

d An agent of the Trunk Line Association will validate certificates, Dec. 7, 8, 9. No refund of fare will be made on account of failure to have certificate validated.

e One-hundred certificates and round trip tickets must be presented for validation before the plan is operative. This makes it important to show the return portion of your round trip ticket at Headquarters.

f If certificate is validated, a return ticket to destination can be purchased, up to Dec. 13, on the same route over which the purchaser came, at three-fifths the rate.

This special rate is granted only for the following:
Trunk Line Association:

All of New York east of a line running from Buffalo to Salamanca, all of Pennsylvania east of the Ohio River, all of New Jersey, Delaware and Maryland; also that portion of West Virginia and Virginia north of a line running through Huntington, Charleston, White Sulphur Springs, Charlottesville, and Washington, D. C.

New England Passenger Association, except Eastern Steamship Co. and Metropolitan Steamship Co.

Maine, New Hampshire, Vermont, Massachusetts, Rhode Island and Connecticut.

Central Passenger Association:

The portion of Illinois south of a line from Chicago through Peoria to Keokuk and east of the Mississippi River, the States of Indiana, and Ohio, the portion of Pennsylvania and New York north and west of the Ohio River, Salamanca and Buffalo, and that portion of Michigan between Lakes Michigan and Huron.

Eastern Canadian Passenger Association:

Canadian territory east of and including Port Arthur, Sault Ste. Marie Sarnia and Windsor, Ont.

PRELIMINARY PROGRAM

TUESDAY, DECEMBER 6

8.30 p.m.

Presidential Address, George Westinghouse.

Report of Tellers of Election of Officers.

President's reception in the rooms of the Society. All members and guests invited. Cards of admission upon application.

Music and refreshments, Chas. W. Aiken, Chairman Sub-Committee in charge.

WEDNESDAY, DECEMBER 7

10 a.m.

Reports of Council, standing and special committees, and tellers of election of membership. New business.

The Joint Meeting in England: Report by the Secretary.

The Transmission of Heat in Surface Condensation, George A. Orrok.

2 p.m.

Combustion and Boiler Efficiency, Edw. A. Uehling.

Automatic Control of Condensing Water, B. Viola.

Test of a 10,000-kw. Steam Turbine, Sam. L. Naphtaly.

Test of a 9000-kw. Turbo-Generator Set, F. H. Varney.

Notes on the Value of Napier's Coefficient with Superheated Steam, Isaac Harter, Jr.

9 p.m.

Reunion of the membership in Hotel Astor. Dancing and Refreshments.

Robert S. Allyn, Chairman Sub-Committee in charge of Reunion.

THURSDAY, DECEMBER 8

10 a.m.

A New Theory of Belt Driving, Selby Haar.

Stresses in Connecting Rods, W. H. Herschel.

Operating Conditions of Passenger Elevators, Reginald P. Bolton.

Modern Shoe Manufacture, M. B. Kaven and J. B. Hadaway.

Simultaneous Sessions, 2 p.m.

MACHINE SHOP

The Field for Grinding, C. H. Norton.

Precision Grinding, W. A. Viall.

Modern Grinding Methods, B. M. W. Hanson.

Gas Power Section

Business Meeting.

First Large Gas Engine Installation in American Steel Works, E. P. Coleman.

Other Gas Power papers as assigned.

Reception to members and guests by Mr. and Mrs. Westinghouse, Hotel St. Regis, 4 to 6 p. m.

8.15 p.m.

Address: Industrial Continuation Schools of Munich, Dr. Georg Kerschensteiner, Superintendent of Schools, Munich, Bavaria.

FRIDAY, DECEMBER 9

Excursions to points of engineering interest.

COMING MEETINGS

MEETING IN ST. LOUIS, DEC. 10

The next monthly meeting of the Society at St. Louis will be held on the evening of December 10, the Engineers Club of St. Louis coöperating.

MEETING IN BOSTON, DEC. 16

At the meeting of the Society in Boston for December a paper will be presented by Samuel B. Fowler, Consulting Engineer, Boston, on Terminal Facilities for Handling Freight. The Boston Society of Civil Engineers and the Boston Section of Institute of Electrical Engineers willl coöperate.

REPORT OF MEETINGS

MEETING IN NEW YORK, NOVEMBER 9

The New York monthly meeting for November was held on the ninth, the day following the regular time for the meeting, owing to Election Day coming on that date. The attendance was 163.

The first half of the session was devoted to a paper on the Rotary Kiln by Ellis Soper, Mem.Am.Soc.M.E., of Detroit, Mich., which was read by Prof. R. C. Carpenter of Ithaca, New York, Vice-President Am.Soc.M.E., in the absence of the author. Following this paper was an address on the Panama Canal by Charles Whiting Baker, Vice-President Am.Soc.M.E., editor of Engineering News. Mr. Baker discussed the methods used in carrying on the construction work at the canal, illustrating his talk with pictures taken at the time of his visit in 1909, when accompanying the engineering commission appointed by President Roosevelt. Mr. Baker said that the Canal is to be regarded as a problem in transportation as, in fact, practically everything is a problem of this type. Things are not made or manufactured, but one sort of material is merely taken from one place and put into another. The digging of the canal is easier and simpler than the carrying away to a distance of several miles of the material dug out by the great steam shovels, which remove 5 cu. yd. at a movement. But even this is cheaper than to pile the material on the high banks of the canal.

A greater problem, even, than this one of the removal of earth is the caring for the big working force of 30,000 laborers and 5000 skilled workmen, comprising over a score of different nationalities and all social grades. Moreover, everything needed to build the canal,—tools, machines, cars, locomotives, lumber,—and to make comfortable the great force of men and their families, had to be brought 2000 miles.

The engineers at the Canal had taken up many of their burdens, not through choice, but of necessity, for conditions had to be met as they arose, and they should rather be honored than criticised for their achievements, by none more than by their professional brethren.

MEETING IN BOSTON, NOVEMBER 10

The first monthly meeting of the Society in Boston for the present season was held on the evening of November 10 in the auditorium of the Edison Company, with the Boston Society of Civil Engineers and the Boston Section of the American Institute of Electrical Engineers coöperating The attendance was 150.

After a brief business session, at which a nominating committee to select a new Committee on Meetings of the Society in Boston was appointed, a topical discussion on Smoke Abatement was opened by Dwight T. Randall, Mem.Am.Soc.M.E., who made a statement of the case as applied to New England. He was followed by E. G. Bailey, Frederick H. Keyes, Charles H. Manning, Henry Bartlett, George H. Barrus, John T. Hawkins and C. H. Bigelow. Mr. Randall said that ordinances making it unlawful to produce smoke are not in themselves effective and that results can be accomplished only by recognizing the difficulties and overcoming them along engineering lines. Leading up to the all-important question of the combustion of bituminous coal, he discussed the relation of volatile matter to smoke and the effect upon combustion of ash, moisture and the size of the coal. He discussed the design of furnaces for bituminous coal, including brick work, baffles, arches, etc., and questions of air supply, the prevention of smoke during hand-firing and the use of stokers. The mere installation of the latter, he said, will not insure smokeless combustion, but the questions of draft and its regulation and other engineering conditions must be considered. Numerous tests were presented of the performance of boilers with different fuels.

MEETING IN ST. LOUIS, NOVEMBER 12

A meeting of the St. Louis members of the Society was held on Saturday evening, November 12, at the Mercantile Club. At the conclusion of dinner, the meeting was called to order by Wm. H. Bryan, Chairman of the Committee on Meetings in St. Louis. On motion the present committee, consisting of Wm. H. Bryan, M. L. Holman, E. L. Ohle, F. E. Bausch and R. H. Tait, was reëlected for one year, subject to the approval of the Meetings Committee of the Society and of the Engineers' Club of St. Louis, with whom meetings are usually held. The method heretofore followed in the conduct of local meetings was approved, and it was voted that for the present the meetings continue to be conducted jointly with the Engineers' Club of St. Louis. A general discussion of local business followed.

MEETING OF THE COUNCIL

A meeting of the Council was held on the afternoon of Wednesday, November 9, 1910, in the rooms of the Society, and was called to order at 3.30 p.m. by the President. There were present, George Westinghouse, Chas. Wallace Hunt, Fred. W. Taylor, Chas. Whiting Baker, George M. Bond, R. C. Carpenter, E. D. Meier, Fred. M. Whyte, J. Sellers Bancroft, James Hartness, I. E. Moultrop, H. G. Reist, Wm. H. Wiley and the Secretary. Regrets were received from W. F. M. Goss, H. L. Gantt, C. E. Billings, Oberlin Smith and Robert W. Hunt.

The minutes for the meeting of October 11 were read and approved.

The President appointed Chas. Wallace Hunt, Chas. Whiting Baker and J. Sellers Bancroft tellers to count the Ballots for Life Membership of W. F. Mattes of Scranton, Pa., and S. B. Whiting of Cambridge, Mass., under the provisions of C 23 and B 36 of the Constitution and By-Laws. The President later announced their unanimous election.

The Secretary announced the following deaths: Clay Belsley, Peoria, Ill., F. B. Hall, New York, Washington Jones, Philadelphia, Pa., O. S. Shantz, Buffalo, N. Y., F. M. Wheeler, New York, A. Wilkinson, Bridgeport, Pa.

Voted: To accept the resignations of John S. Naylor, Henry Brewer, Geo. W. Heald, Jr., Gustav Kaffenberger, Fred Nolde, O. S. Porter, Fred. W. Gordon, George Berna, Jarred E. Jones.

Announcement was made of the appointment by the President of a Public Relations Committee, under the provisions of C 45, consisting of James M. Dodge, Chairman, Robert W. Hunt, D. C. Jackson, J. W. Lieb, Jr., Fred J. Miller.

Voted: To accept the reports of the standing committees presented by the Secretary and that so much of these reports be printed in the next number of The Journal as in the discretion of the Secretary may seem proper.

The Secretary read a letter from the Third Assistant Postmaster General granting extension of time.

Voted: In accordance with the recommendation of the Publication Committee to appoint Wm. H. Wiley, Treasurer, and Calvin

W. Rice, Secretary, a committee to confer with the Post Office Department in Washington with a view to establishing our claim for second class entry of The Journal.

Voted: To refer to the Publication Committee with the suggestion that they again confer with Vice-President Baker and report to the Council.

The Secretary presented communications to the Council in connection with the ballots for officers of the Society.

It was also announced that a committee of members was in the reception room and desired to be permitted to present the same matter to the Council in person; a statement was made of the action which the Secretary had taken and of the authority under which he had acted. The following committee of members was then invited to the Council room: Messrs. H. F. J. Porter, H. H. Suplee, E. G. Spilsbury, Wm. H. Boehm, H. L. Aldrich. Mr. Porter presented a letter to the Council. A full discussion followed.

Voted: To refer the matter to the Executive Committee with the request that that Committee take advice of counsel and report at an adjourned meeting of the Council.

Voted: To adjourn subject to call of the Executive Committee.

SPECIAL MEETING

An adjourned meeting of the Council was held on the afternoon of Wednesday, November 16, 1910, in the rooms of the Society, and was called to order at 3.30 p.m. by Vice-President Meier. There were present, George M. Bond, Chas. Whiting Baker, James Hartness, F. R. Hutton, Jno. R. Freeman, E. D. Meier, Jesse M. Smith, H. G. Reist, Fred. W. Taylor, Fredk. M. Whyte and the Secretary. Regrets were received from I. E. Moultrop and J. Sellers Bancroft.

The minutes of the meeting for November 9 were read and approved.

Vice-Chairman Chas. W. Baker read the report of the Executive Committee on the matter of the Ballot for Officers for the year 1910 1911.

Voted: That the report of the Executive Committee be received and placed on file.

The Council then took up seriatim the resolutions embodied in this report, with the following action:

Voted: That after consideration of the communication of November 7, the Council deems it unwise to interfere with the election now in progress and directs that it proceed in the same manner in which it has been conducted in previous years.

Voted: To adopt the following rule:

35 The tellers of election in counting the ballots for officers shall consider the ballot for an officer as valid, provided the intent of the voter as to that particular office is clear, even though his ballot as to candidates for another office may for any reason be invalid.

Voted: That the Council approves the form of ballot distributed by the members and decides that it is in conformity with the Constitution and By-Laws of the Society in particular with B 14, B 29 and B 30.

Voted: That in view of the opinion of our legal advisor, the ballots which have been distributed are in accordance with the previous precedents of the Society and are deemed to be legal ballots.

Voted: That what appears to be a discrepancy between the Charter of 1907 and the existing By-Laws of the Society in connection with the dates of the Annual Meeting of the Society be referred to the Committee on Constitution and By-Laws for consideration and report previous to the Annual Meeting of 1910.

Voted: That a summary be made of the action taken by the Council on the communications received by it in connection with the Ballot for Officers, such summary to be sent to each member who makes inquiry concerning the ballot, and also to the Special Nominating Committee, and that a summary be included in the account of the proceedings of the Council as is regularly published in The Journal.

Voted: On recommendation of the Chairman of the Committee on Student Branches, that the formation of such student branch at Rensselear Polytechnic Institute be approved.

Voted: To approve the formation of a student branch at the Washington University, St. Louis, Mo.

Voted: That the Honorary Secretary be requested to make a report to the Council of the Joint Meeting of the Society held in England during the past summer.

Voted: To adjourn to Tuesday, December 6, at 2.30 p.m. and that 2.30 p.m. be the regular hour for Council meetings until further notice.

STUDENT BRANCHES

The following officers have been elected at the Brooklyn Polytechnic Institute for the year 1910–1911: Chairman, A. L. Palmer, Vice President, Mr. Siebert, Secretary, R. C. Ennis, Treasurer, Henry Priester. At the meeting on October 15, Lester G. French, Editor of The American Society of Mechanical Engineers, spoke to the society on Technical Publications. At the November 5 meeting Mr. Foster of the New York School of Automobile Engineers addressed the members.

The Purdue University Student Branch was addressed on November 2 by Prof. H. O. Garman, of the Civil Engineering Department of the University, on Railway Signalling Devices; and on November 16 by E. C. Clarage of the Columbia Tool Steel Company upon Tool Steel.

At the November meeting of the Sibley College Student Branch, David S. Wegg, Jr., Jun.Mem.Am.Soc.M.E., was elected corresponding secretary to succeed Prof. C. F. Hirshfield, resigned.

On Tuesday, November 1, I. E. Moultrop, Mem.Am.Soc.M..E, lectured before the Stevens Engineering Society on The Design and Construction of a Central Power Station, giving the latest ideas and practice which govern the location and equipment of such a plant, illustrated by a number of slides, including a remarkable series of photographs of Boston taken from the top of the tall chimney of the central station. On November 15, Dr. James P. Haney, lecturer and director of art in the high schools of New York City, addressed a large audience on the advantages of a knowledge of the principles of art in the field of engineeering.

At the first regular meeting of the University of Cincinnati on October 21, a talk was given by A. L. DeLeeuw, Mem.Am.Soc.M.E., chief engineer of the Cincinnati Milling Machine Company, on Milling Cutters. This was illustrated by a large number of lantern slides.

At the October meeting of the University of Illinois, A. Bement, Mem.Am.Soc.M.E., addressed the membership on The Coal Problem.

At a meeting of the Wisconsin Student Branch held on November 3, two new students were admitted as members. J. S. Langwill presented a paper upon Machines for the Spinning Industry and E. F. Week gave a talk upon a Projected Water Power Plant in the West.

NECROLOGY

FREDERICK BELLOWS HALL

Frederick Bellows Hall, Member of the Society, was born October 18, 1868, at Boston, Mass. He received his technical education at the Massachusetts Institute of Technology and after graduation in 1890, was employed by the West End, now known as the Boston Elevated Street Railway Company, as draftsman on the design of their Central Power Station. The following year as chief draftsman with F. S. Pearson, consulting engineer, Boston, he designed various power stations, among them the Brooklyn City Railroad Company, Brooklyn, N. Y., Montreal Street Railway Company, Montreal and Quebec, St. Johns Street Railway Company, St. Johns, N. B., Halifax Street Railway and Lighting Company Halifax, N. S., Chelsea Gas Lighting Company, Chelsea, Mass., Charlestown Gas Company, Boston, Mass., Lawrence Gas Lighting Company, Brighton, Mass. During this time he also acted as superintendent of construction of power stations for the Baltimore Electric Refining Company, Baltimore, Md., Dover Lighting and Power Company, Dover, N. H., and the Portland Street Railway Company, Portland, Me. He was subsequently employed as assistant chief engineer of the Brooklyn City Railroad (Brooklyn Rapid Transit) Company in charge of the design and construction of their Kent Avenue, Southern and Ridgewood Power Stations; and in 1894 had charge of the design and construction of the main power station of the Consolidated Traction Company (now the Public Service Corporation of New Jersey), Newark, N. J. In 1895 he engaged in the design of apparatus for the manufacture of sulphuric acid, and in the following year was employed by J. H. Bickford as consulting engineer in charge of the design of a power station for the Steinway Railway Company. In the same year he became treasurer and general manager of the North Sydney Mining and Transportation Company, Sydney, Cape Breton, N. S., leaving there to become chief draftsman for the Riter-Conley Manufacturing Company of Pittsburgh in charge of the design of blast furnace and steel works for the Dominion Iron and Steel Company of Cape Breton.

From 1899 to 1901 he was engaged on the design and construction of the main power station of the Manhattan Elevated Railway Company, New York City, and at the time of his death, October 27, 1910, was in the employ of W. E. Baker and Company.

WASHINGTON JONES

Washington Jones, who died on July 30, 1910, was born in Philadelphia, February 22, 1822, and became an apprentice at the works of Merrick and Agnew at fifteen years of age—the first apprenticeship taken in that establishment, it is said. His industry and capacity were attested by his advancement to positions of responsibility there and in several other engineering works of Philadelphia, such as the Southwark Foundry, Merrick and Towne, and the Penn Treaty Works of the Neafie and Levy Ship and Engine Building Company. He was associated with the Port Richmond Iron Works of the I. P. Morris Company as constructing engineer from 1856 to 1891 with a brief interruption of a few years at the Southwark Foundry, when he bore an important part in the productions of that establishment during the Civil War.

Mr. Jones had been a member of the Society since 1880. He was also an honorary member and past president of the Engineers' Club of Philadelphia, a member of the American Society of Civil Engineers and the oldest surviving member of the Franklin Institute of which he was vice-president at the time of his death.

STILLMAN W. ROBINSON

Stillman Williams Robinson, Member of the Society, died October 31, 1910, at his home in Columbus, O. He was born near South Reading, Vt., March 6, 1838, and earned the money to defray the expenses of his early education and to prepare himself for college as an apprentice to the trade of machinist. In 1860 he entered the University of Michigan, making his way to Ann Arbor mostly on foot and meeting his expenses on the way by working as a machinist. From here he was graduated in 1863 with the degree of C.E., having supported himself throughout the college course by skilled instrument making, while there inventing a machine for graduating thermometers, a work in which he was particularly interested. After graduation he entered the government service as assistant engineer in the United States Lake Survey, remaining until 1866 when he returned to his alma mater as an instructor in engineering. In 1870 he became professor of mechanical engineering and physics in the Illinois Industrial University, now the University of Illinois, establishing the first department of mechanical engineering in this country; and in 1878 was made dean of the College of Engineering. In the same year he was called to Ohio State University as professor of physics and mechanical engineering and occupied that chair until 1895 when he resigned in order to devote his time to his extensive professional interests.

Professor Robinson was the author of a number of important books and papers presented before various societies. He also secured about forty patents, many of which were fundamental and of great value. His inventions were based upon scientific research and mathematical investigation and were the results of skillful study. When the Ohio gas fields were first discovered, the problem of measuring the volume of flow was referred to Professor Robinson and solved by him in his brilliant application of the Pitot tube, resulting in methods now in universal use.

His interest in education was always great and led him in 1890 to organize an association composed of teachers of mechanical engineering which in 1893 developed into the present Society for the Promotion of Engineering Education. His interest in the University of Ohio did not cease with his retirement and he made at various times valuable donations to the equipment of its department of mechanical engineering, finally establishing the Robinson fellowship in engineering as a permanent foundation.

The following minute was adopted by the faculty of the Ohio State University, at its last meeting:

As a man, Professor Robinson was an indefatigable worker. There was no limit to his enthusiasm and ambition in his profession. Personally, he was modest and retiring, never claiming credit for himself though most generous in according it to his associates. He was greatly interested in the work of those around him, impressing his own enthusiasm upon the efforts of both colleagues and students, encouraging, stimulating and rewarding them. His memory and influence will long be felt in the lives of those who follow him and who have taken up his work.

REPORTS OF STANDING COMMITTEES TO THE COUNCIL

REPORT OF THE FINANCE COMMITTEE

After one of the most active years in the history of the Society your Committee is gratified in being able to present a financial report which indicates growth and prosperity financially as well as technically.

Although the current expenses of the Society were larger than in any time in its history, yet as will be seen from the appended reports the current income has met the expenses in full and has enabled us to cancel in this one year all of the extraordinary expenses up to date, due to the Joint Meeting with the Institute of Mechanical Engineers in England the past summer, and also to add to our surplus account. This has been made possible from the fact that our excess of income over expenses for the year was $10,649.41.

It is also interesting to note that at the close of the fiscal year our entire surplus represented by property and accounts receivable was $6,433.56 greater than September 30, 1909.

The Committee regret to record that no specific results have been attained during the year just closed in the direction of reducing our mortgaged indebtedness. The total amount received during the past year to the credit of the land fund was not the equivalent of one-fifth of the interest on the mortgage, thereby making it necessary to look elsewhere to meet this interest charge.

It seems to the Committee that there is an urgent necessity for a strong effort to be made to reduce this mortgaged indebtedness materially each year until it is wiped out, and the interest money thereby made available for the extension of our Society work.

Herewith are given the detailed statements of the financial condition of the Society, together with the reports of Peirce, Struss & Co. of New York, certified public accountants, who have audited the books and accounts, and also a statement of the condition of the various trust funds for the fiscal year.

PEIRCE, STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS
37 Wall Street, New York

October 26, 1910

MR. ARTHUR M. WAITT,
CHAIRMAN FINANCE COMMITTEE

Dear Sir:

In accordance with your instructions, we have audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1910.

The results of this examination are presented in three exhibits, attached hereto, as follows:

Exhibit A Balance Sheet, September 30, 1910
Exhibit B Income and Expenses for the year ended September 30, 1910.
Exhibit C Receipts and Disbursements for year ended September 30, 1910.

We beg to present, attached hereto, our Certificate to the aforesaid exhibits.

Respectfully submitted,
PEIRCE, STRUSS & CO.
Certified Public Accountants

PEIRCE, STRUSS & CO.
CERTIFIED PUBLIC ACCOUNTANTS
37 Wall Street, New York

October 26, 1910

MR. ARTHUR M. WAITT,
CHAIRMAN FINANCE COMMITTEE

Dear Sir:

Having audited the books and accounts of The American Society of Mechanical Engineers for the year ended September 30, 1910, we hereby certify that the accompanying Balance Sheet is a true exhibit of its financial condition as of September 30, 1910, and that the attached statements of Income and Expenses, and Cash Receipts and Disbursements are correct.

PEIRCE, STRUSS & CO.
Certified Public Accountants

EXHIBIT A

BALANCE SHEET, SEPTEMBER 30, 1910

ASSETS

Equity in Societies Building (25 to 33 West 39th Street)	$353 346.62	
Equity one-third cost of land (25 to 33 West 39th Street)	180 000.00	
		$533 346.62
Library Books	13 000.00	
Furniture and Fixtures	5 000.00	
		18 000.00

New York City 3½% Bonds 1954		
Par $35,000	30 925.00	
Cash in Bank representing Trust Funds	11 356.59	
		42 281.59
Stores including plates and finished publications		11 623.03
Cash in Bank for general purposes	3 611.73	
Petty Cash on hand	250.00	
		3 861.73
Accounts Receivable		
Membership dues	9 554.50	
Initiation fees	540.00	
Sale of publications, advertising, etc	6 360.04	
		16 454.54
Advances account of land subscription fund		9 955.22
Advanced payments		1829.65
Total Assets		$637 352.38

LIABILITIES

United Engineering Society (for cost of land)		$81 000.00
Funds		
Life Membership Fund	$35 151.07	
Library Development Fund	4 902.71	
Weeks Legacy Fund	1 957.00	
Land Fund Subscriptions	223.88	
Subscriptions to Annual Meeting	46.93	
		42 281.59
Current Accounts Payable		2 652.33
Membership dues paid in advance	804.25	
Initiation fees paid in advance	75.00	
		879.25
Initiation fees uncollected		540.00
Appropriation available to complete Vol. 31 of Transactions		4 200.00
Reserve (Initiation fees)		27 926.97
Surplus in property and accounts receivable		477 872.24
Total Liabilities		$637 352.38

EXHIBIT B

Income and Expenses for the Year Ended September 30, 1910

INCOME

Membership dues	$ 57 551.79	
Sales gross receipts	9 210.25	
Advertising receipts	24 230.26	
Interest and Discount	1 684.01	
		$92 676.31

EXPENSES

Finance Committee Office Administration including Salaries	$20 205.68		
Finance, United Engineering Society Assessments	4 500.00		
Finance, Miscellaneous	634.36		
		$25 340.04	
Membership Committee		2 350.49	
Increase of Membership Committee		2.70	
§House Committee			1 089.16
Library Committee			2 491.46
Meetings Committee			
Annual Meeting	2 394.40		
Spring Meeting	2 028.72		
Monthly Meetings	3 416.92		
London Meeting	2 270.23		
		$10 110.27	
Publication Committee			
Advertising Section The Journal	11 791.32		
Journal, except Advertising	18 527.88		
Year Book	2 748.73		
Revises	131.96		
Transactions Volume 31	2 801.79		
		$36 001.68	
		$77 385.80	
Research Committee		100.76	
Thurston Memorial Committee		139.06	
Sales Expenditures		4 401.28	
Total			$82 026.90
*Excess of Income over Expenses			10 649.41
			$92 676.31

§From Current Income	$1,089.16
Reserve Fund	3,000.00
Total Expenses	$4,089.16

*Of this amount $4,200.00 is reserved to complete Volume 31 of Transactions.

EXHIBIT C

Receipts and Disbursements for Year Ended September 30, 1910

RECEIPTS

Membership dues	$49 888.25	
Initiation fees	6 345.00	
Membership dues and initiation fees paid in advance	948.00	
Sales of publications, badges, advertising, etc.	31 733.56	
Subscriptions to Land Fund	616.00	
Subscriptions to Expense of Annual Meeting	360.20	
Interest	2 168.23	
	$92 059.24	
Cash in Banks and on hand, September 30, 1909	20 613.22	
		$112 672.46

DISBURSEMENTS

Disbursements for general purpose	94 214.14	
Interest on Mortgage on Land	3 240.00	
	97 454.14	
Cash in Banks and on hand, September 30, 1910	15 218.32	
		$112 672.46

LAND FUND

RECEIPTS

Subscription	$71 662.76
Interest	573.56
Advances from Society	9 955.22
Property, 12 W. 31st St.	63 000.00
	$145 191.54

DISBURSEMENTS

Acquisition of property	7 971.11	
Mortgage	99 000.00	
Interest	27 766.92	
Furnishings and equipment	7 671.81	
Occupancy building, moving library	2 171.06	
Expenses of Committee	386.76	
Cash on hand	223.88	
		$223.88
	145 191.54	

Cash on hand	223.88	
To be raised	90 731.34	
	90 955 22	
Amount of mortgage	81 000.00	
Advances by Society	9 955 22	
	90 955.22	

LIFE MEMBERSHIP FUND

Number of Life Members	90	
Number of Life Associates	6	
Number of Life Juniors	1	
	97	
97 Members at $15 = $1455		
4 per cent interest on $35,151.07 and credited to unappropriated revenue	$1 406.04	
Amount Oct. 1, 1910	35 151.07	35 151 07

LIBRARY DEVELOPMENT FUND

Amount Oct. 1, 1909	4 902.71	
Balance Oct. 9, 1910		4 902.71

WEEKS LEGACY

Amount Oct. 1, 1909	1 957.00	
Balance Oct. 1, 1910		1 957 00

THURSTON MEMORIAL FUND

Subscriptions	788.32	
Interest	36.47	
Current Income 1909 1910	139.06	
	963.85	
Expenditures		
Bronze Memorial	850.00	
Reflector bracket	30.00	
Booklet	32.04	
Committee expenses	51.85	
	963.85	

ANNUAL MEETING SUBSCRIPTION

Balance in the hands of the Local Committee and held by the Society in trust		46.93
		$42 281 59

The Committee also submits herewith as called for by the By-Laws a detailed estimate of the probable income and expenditure of the Society for the ensuing fiscal year:

ESTIMATE OF INCOME 1910-11

Dues	$57,525
Sales, gross receipts	5,000
Interest and discount	475
Advertising	25,500
	$88,500

ESTIMATE OF EXPENSES 1910-11

	FROM CURRENT INCOME	FROM RESERVE
Finance Committee	$28,740	
Membership Committee	2,450	
Increase Membership Committee	500	
House Committee	600	$ 400
Library Committee	4,500	
Meetings Committee	9,000	
Publication Committee	36,400	*1500
Research Committee	300	
Public Relations Committee	100	
Committee on Power Tests	300	
Sales Expenditure	3,000	
Reserve Fund	600	
	$86,490	$1900

Respectfully submitted,

ARTHUR M. WAITT, *Chairman*
R. M. DIXON
E. F. SCHNUCK
W. M. MARSHALL
G. W. ROBERTS
Finance Committee

REPORT OF THE HOUSE COMMITTEE

Your Committee during the year has completed the work embodied in the decorative scheme outlined in its last report. This included the tinting of the walls and the furnishing of new carpets, new draperies and new furniture in the entrance hall, Council room and library. It is felt that these rooms now present an attractive, quiet and dignified appearance appropriate to the home of the Society.

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* Advanced on account meeting in England to be paid out of current income.

Your Committee also acquired a uniform series of photographs of all the Past-Presidents, which are now hung upon the walls of the library.

Your Committee has in mind the extension of its original program with a view to unifying the plan of decoration in such of the rooms as are open to the general public, and hopes to carry out these plans during the coming year.

Your committee further proposes to secure photographs of the Honorary Members, to be framed in conformity with the photographs of the Past-Presidents already hung upon the walls.

Respectfully submitted,

William C. Dickerman, *Chairman*
Bernard V. Swenson
Francis Blossom
Edward Van Winkle
H. R. Cobleigh
House Committee

REPORT OF THE LIBRARY COMMITTEE

No radical changes have been effected in the library organization during the past administration year.

The libraries of the three founder societies are being operated in parallel, the actual library work being handled jointly by the library staff and the administration of the libraries being conducted under an informal Library Conference Committee consisting of the chairman of the library committees of the founder societies.

It is expected that more intimate relationships between the libraries will be established in the near future.

It is also expected that the United Engineering Societies' library will be organized and that gifts of libraries and books may be received by it where they are not made a specific donation to the library of one of the founder societies.

The number of visitors accommodated at the library shows a continued increase as indicated by the following tabulations:

	Day	Night	Total
July	609	Closed	609
August	560	Closed	560
September	596	261	857
	1765	261	2026
Night	261		
Total	2026		

	1908		1909		1910	
	Day	Night	Day	Night	Day	Night
January	541	148	485	250	460	286
February	439	241	533	254	416	232
March	417	203	535	280	439	256
April	403	210	529	217	488	274
May	400	196	462	221	454	279
June	419	136	484	198	471	239
July	441	closed	472	closed	609	closed
August	362	closed	472	closed	560	closed
September	393	125	434	220	596	261
October	381	180	471	238		
November	435	200	479	223		
December	520	441	545	301		
	5151	2080	5901	2402	4493	1827

Membership cards received

American Institution Electrical Engineers	10
American Society Mechanical Engineers	8
American Institution Mechanical Engineers	20
Non-members	8
	46

As an indication of the range of subjects called for by visitors to the library and the relative frequency of consultation, the following table may be of interest, covering the months of April–September 1910.

	April	May	June	July	Aug.	Sept.
Architecture	1	2	1		1	1
Bibliography						2
Biography	1				1	1
Chemical Technology	4	5	4	2	3	1
Chemistry	4	4	2	1	2	2
Civil Engineering	7	1	5	2	2	5
Description and Travel	1	1	1	1		
Electrical Engineering	17	12	22	6	20	14

	April	May	June	July	Aug.	Sept.
Electricity	2	9	1	5	5	1
Engineering (General)	5	6	14	5	10	10
Geology	22	9	10	7	24	20
Hydraulic Engineering	2	3	4	2		10
Mathematics	5		1	1		9
Marine Engineering						
Mechanical Engineering	27	23	26	13	16	19
Metallurgy	14	4	11	13	4	1
Mining Engineering	16	11	20	9	9	6
Miscellaneous	1		3	4	1	4
Periodicals	49	28	89	30	39	90
Physics	7	2	2	3		7
Railroad Engineering		5		1		5
Railroad Engineering (Electrical)	1					7
	196	125	216	105	137	215

It has been felt that the appropriation available for the purchase of new books is inadequate to keep the library supplied with the latest books of reference.

The amount expended for books and periodicals in 1908 was $527.76. An approximately similar amount will be expended during the current year and your Committee in presenting its request for the appropriations for next year has submitted a request that the appropriation under this head be increased to $1500.

Your Committee has in preparation a book plate for the Society's library which will be submitted for the approval of Council of the Society at an early date.

Respectfully submitted,

J. W. Lieb, Jr., *Chairman*
Ambrose Swasey
Leonard Waldo
Chas. L. Clarke
Alfred Noble
Library Committee

REPORT OF THE COMMITTEE ON MEETINGS

In addition to the Annual and Spring Meetings of the Society, 18 additional meetings have been held. Of this number six were held in each of the cities of New York, Boston and St. Louis. During 1910 and 1911 meetings will also be held in San Francisco. At a number of these meetings sister societies and local engineering organizations coöperated, but the number of meetings given does not include those of other societies in which we coöperated.

It is the policy of your committee to meet weekly, excepting during the summer months, and including special meetings the Committee has practically carried out this policy during the period mentioned.

Fifty-four papers and three topical discussions have been accepted and published in The Journal, all of which have been or will come before meetings of the Society. These include eight papers presented at the meetings held at Birmingham and London.

Several cities other than New York, Boston, St. Louis and San Francisco are contemplating holding meetings, but they have not as yet reached a definite conclusion.

It has been suggested that appropriations be assigned for meetings, based on the number of members accessible to a locality. For the present, however, your Committee believes that the Society should do all possible to assist the membership in different localities in which these meetings are being held, to the limit of the available funds.

Your Committee finds that the local conditions vary at the different points and therefore repeats the suggestion contained in its report to the Executive Committee of May 31, 1910, that after more extensive experience of all the local committees on meetings has been obtained, they, in coöperation with the Committee on Meetings, formulate such rules as may be found necessary to establish uniformity in the conduct of all local meetings, the same to be subject to the approval of the Council.

A meeting of the local members at New York was held October 31, 1910, for the recommendation of names for a local committee, that New York City may be organized on the same basis as all other localities. It is intended that this committee, by the selection of some 20 assistants, shall also act as the entertainment committee for the Annual Meeting.

Your Committee has felt for some time that the papers presented before the Society have not been sufficiently diversified. It believes that it has overcome this to some extent, but with the further object of making the Transactions of the Society a more complete record of mechanical engineering progress, a circular has been mailed to the membership calling their attention to this point, which it is believed will result in materially increasing the value of the Transactions of the Society as a record of engineering progress. The attention given the circular so far is most gratifying and the membership is to be congratulated upon the interest it has inspired.

The rapid growth of industrial establishments has developed a phase of mechanical engineering—that of economic administration—which your Committee feels should be given the attention by the Society that its importance warrants. This branch of the profession has evolved the administrative engineer until a very large percentage of the profession and of our membership is now occupying administrative positions in industrial establishments. Your Committee has had this question under attention for some time, but until recently it did not feel that the opportune time for definite action had arrived.

At its meeting, October 7, 1910, it requested the endorsement by the Council of the appointment of a sub-committee on the Economic Administration of Industrial Establishments. The committee is glad to have the Council's approval of its request and we believes the field covered by this sub-committee can be made one of the greatest factors in our economic welfare.

Permit the Committee again to call the Council's attention to the recommendation that it feels the best interests of the Society would be subserved by a closer working arrangement between the Research Committee and the Committee on Meetings.

The Committee begs to thank the officers of the Society and the members of the office staff for the coöperation and assistance it has received.

Respectfully submitted,
Willis E. Hall, *Chairman*
Wm. H. Bryan
L. R. Pomeroy
Chas. E. Lucke
H. deB. Parsons
Meetings Committee

REPORT OF THE MEMBERSHIP COMMITTEE

During the current year the Membership Committee has held six meetings, at which the total of 337 applications for membership have been considered with the following results:

Withdrawn for various causes	14
Deferred indefinitely	17
Recommended for membership	306

Of the 306 names recommended for ballot 276 were candidates for new membership and 30 were candidates for promotion. The candidates recommended were voted for on two ballots submitted to the membership as follows:

Spring ballot	159
Fall ballot	147

The small number of names deferred and the fact that no objections have been received to the names placed upon the professional service sheets testifies to the increasing care taken by the members in filling out the application blanks, and to the careful manner in which all cases are studied in the Secretary's office before being submitted to the committee. The Committee, however, would emphasize again that its work will be greatly facilitated and the standards of the Society safeguarded if members will agree to act as proposers and seconders of an applicant only when they can support the latter through personal knowledge of his work.

The Committee desires to report that the new rules regarding the Junior and the Associate membership grades put into effect at the spring meeting, have operated upon the whole in a very satisfactory manner, and in the judgment of the committee have placed the classes of membership upon a basis that makes for the best interests of the Society.

The Committee would recommend that it be given authority to prepare a list of approved engineering schools that will be used to interpret the phrase "engineering schools" in clause C-11 of the Constitution relating to the admission of Junior members.

Respectfully submitted,

C. R. Richards, *Chairman*
George J. Foran
Theodore Stebbins
Francis H. Stillman
Hosea Webster
Membership Committee

REPORT OF PUBLICATION COMMITTEE

The Committee has had to meet the constantly growing number and length of papers presented to the Society by the members of its annual, monthly and local meetings by a very careful elimination or condensation of everything which might be termed extraneous or superfluous in order to keep within the confines of a single volume of the Transactions.

Volume 31, just issued for 1909, contains 1069 pages and the current Volume 32 embracing, in addition to the Society papers, the papers presented at the English meeting will contain between 1500 and 2000 pages. This would be considered the outside limit of size.

The largest volume heretofore printed was No. 24 for 1903 which contained 1563 pages and was thought unwieldy, and yet if the growth of our available matter continues at anything like its present rate, we will be confronted with the necessity of binding Transactions in volumes of about this size. An alternative would be the omission of the printing of the Transactions altogether as such, thereby avoiding the duplication of 75 per cent of the reading matter of The Journal.

This would be done by printing in The Journal previous to meetings a list only of the papers which will be read at the meeting, requesting members who desire to discuss any particular paper to send for a copy of it. After the meeting, The Journal would publish all papers with all discussions and at the end of the year would supply binders in which all copies of The Journal may be bound. This volume would continue the present series of Transactions. By this means the papers would be printed once only instead of twice and the annual saving to the Society would be approximately $5000, which could be applied to making the Library more accessible to members.

Previous to this year, The Journal has been published monthly, except in July and August when there were no issues, and in October and November to accommodate the additional amount of matter necessitated by the Annual Meeting it has appeared semi-monthly. This year however, the arrangement has been changed so as to have it appear monthly throughout the year.

The gross and net cost of issuing the Society publications is given in the following tables for each of the past five fiscal years ending September 30.

EXPENDITURES

	1906–1907	1907–1908	1908–1909	1909–1910	1910–1911
History		$ 95.06	43.65		
Revised papers		182.56	523.93	131.96	300
Year Book and Pocket List	2 232.35	2622.57	3000.89	2748.73	3200
Transactions	8 400.20	6100.00	6533.87	7001.79*	8600
The Journal	11 487.98	8425.58	20160.86	30319.20	25800
	22 120.53	17425.77	30263.20	40201.68†	37900

INCOME

	1906–1907	1907–1908	1908–1909	1909–1910	1910–1911
Advertising			11997.50	24227.26	25500
Appropriations	22 120.53	17425.77	18265.70	15974.42	12400

* Approximate.
† Estimated.

It will be seen that the net cost to the Society is gradually being lessened; the slight increase for 1908–1909 being due to the change in the issue of both the Year Book and the Pocket List to a combination of the two in one.

There has never been a complete cross-reference index of the Transaction, and there has been for a long time a crying need for one. Recently the Library Committee has had in mind the indexing of the Transactions of all the Societies and it will be necessary to carry out a complete indexing of our Transactions in this connection. The Committee is now in conference with the Library Committee on the best method of coöperation in this work.

Respectfully submitted,

D. S. Jacobus, *Chairman* H. F. J. Porter Fred R. Low Geo. I. Rockwood Geo. M. Basford	*Publication Committee*

REPORT OF THE RESEARCH COMMITTEE

The last formal meeting of the Research Committee was held December 10, 1909. At that meeting it was agreed that it would be unwise for the Committee to enter at once upon the investigation of problems of research. It was agreed that as a preliminary to actual work there should be on file in the office of the Secretary, a complete list of the college, commercial and other laboratories of the country, the organization of which might permit them to do work in line with the purposes of our Society. In addition to the name and the location of the laboratory, it was proposed to have the name and address of its director and a statement concerning the extent of its staff and equipment, also a list of the subjects which have been investigated and a reference as to where the reports thereof may be fo nd, a statement of the problems now under investigation, and a statement of the field of engineering for which the laboratories are especially equipped. The circulars which have been sent out have been worded so as to make it clear that the Committee does not wish to intrude itself upon the activities of any laboratory, but that the inquiry grows out of a desire on the part of the representatives of a national organization to know how thoroughly the field is now covered. The responsibility for sending out these circulars and for tabulating the information obtained was left with the Secretary of the Society.

It is the understanding of your Committee that the work of gathering this information is now practically complete, and that there is on record in the Secretary's office all information along this line.

It was also agreed that the Committee might properly undertake a research concerning the performance of safety valves, and a circular has been issued designed to develop the most important facts which should be determined concerning the action of such valves. These were sent to 68 safety valve manufacturers, to 125 railroads of 100 miles or over, and to three large boiler manufacturers. Forty-one replies have been received. Eighteen have no information regarding Pop Safety Valves. Nine of the replies are of especial interest and have been abstracted as follows:

The Consolidated Safety Valve Company refers to Mr. Philip Darling's paper before the Society in 1909 and to experiments of Professor Miller of the Massachusetts Institute of Technology. They favor a high lift for steam passage. As to the rating of the various sizes they favor the continuation and duplication of the Darling and Miller tests. Nickel bronze is favored for valve seats and copper bronze with 10 per cent tin for valves. To maintain efficiency they favor keeping the exhaust steam away from the spring, and exposure to air currents for cooling. They consider the aperture has little effect on the capacity but is an important element of the lift. They suggest experiments to develop the effect of temperature and of steady loads and rapidly varying loads, on springs, also a study of the various rules governing sizes and design of various supervising authorities with the aim to develop a safe and uniform rule, applicable to all sizes. They suggest that many common faults of safety valves be made the subject of reports in boiler inspection service. Railroads which have a system of report covering engine failures might also outline the most common troubles with safety valves.

The Ashton Valve Company refers to the tests of Professor Miller, of the Massachusetts Institute of Technology. They favor the low lift from a practical standpoint with 30 years experience. They suggest tests determining a proper rating of safety-valve boiler based on the capacity of relief that the valve should give. They favor high grade composition of bronze metal made of copper and tin about 8 to 1. Regarding efficiency they make outside spring valve with spring free from steam exposure for use where steam temperature is over 400 deg. fahr. As to aperture bevel seat valves 45 deg. angle give best results. Regarding additional facts they express the opinion that it will be difficult to establish a rule adaptable to both stationary and locomotive boilers and they discuss this point at length.

Crane Company know of no reliable data regarding discharge but refer to A. J. Hewling's discussion, in The Journal, June 1909. They are willing to submit valves and take part in public tests in order that reliable data may be had. They favor high grade composition of valve and valve seats and state that they have no experience of springs losing temper. Facts about the effect of the shape of the apertures have led them to adapt a cushion disc and spring which allows the highest lift practicable. As to tests they suggest that the committee provide accommodations where safety valves may be tested under the same conditions and under most careful observation.

The Lunkenheimer Company do not know of any accurate data other than manufacturers tests. They favor a lift of $\frac{1}{16}$ in. to $\frac{5}{64}$ in. They suggest time tests to determine the efficiency and lift of valves with various lifts under a wide range of actual service conditions and pressures. They favor nickel bronze composition, high percentage of nickel for the seat and a high grade steam metal for the disc. The outside spring type of valve is used to avoid undue heat and to maintain the efficiency. As to the shape of the aperture, they suggest six points to be considered. For research they suggest the evolution of a simple and practical rule for determining sizes based on a moderate constant lift.

Crosby Steam Gage and Valve Company have submitted a reply of some thirty pages accompanied by illustrations and catalogues. For data they refer to the Annual Report of the U. S. Steamboat Inspectors, 1877, thesis of Bardsley and Miller, Case School of Applied Science, 1906, data of tests referred to in Steam Boilers by Professor Peabody, p. 240, and tests now being made at Massachusetts Institute of Technology, 1910. Regarding the lift in safety valves they cite the experience of manufacturers' measurements at factories and in actual service, measurements made at the Massachusetts Institute of Technology, 1909. They suggest fixing standard or limits of lift, to insure durability to valves; measuring discharge of various designs of valves at same fixed lifts, reporting minimum lift and discharge which have been in past ample, and refining characteristics of operation most desirable in safety valves. They favor bronze composition, high percentage of tin, low in zinc and lead. Nickel composition not to be endorsed. Exposing springs outside of valve body involves friction; encasing spring in inner chamber involves sticking; long spindles, large valve casings, well drained spring chambers essential without sliding contacts. Regarding open shape of aperture, see tests of Massachusetts Institute of Technology in Steam Boilers by Professor Peabody; also tests in progress at Massachusetts Institute of Technology; also Kent's Pocketbook, p. 724. For research they suggest verbal explanation in detail of essential characteristics of design of each valve as made; of the general principles involved, and defense of engineering reasons, advantages and objections governing each detail; in other words, the engineering "confession of faith" of each manufacturer and his own exegesis of each article of it.

Rock Island Lines: W. A. Nettleton knows of no boiler being blown up because the safety valve fails to properly relieve. Statistics of Mr. Curtis of the Master Mechanics Association Committee indicate very few boilers explode from over pressure, the majority explode from low water, due generally to carelessness. This applies to locomotive service in which the boiler is very closely watched. As to the durability, a number of small valves are preferable to a very large one. He is skeptical regarding the tendency towards a higher lift. He has had no experience as to temper of the spring and steam. He assumes spring losses of elasticity because of repeated strains.

Canadian Pacific Railway Company: Mr. Vaughan, Vice-President, considers it desirable to investigate for flat seats and V-shaped seats. The amount of steam flowing per hour with different heights of lift, the height to which valves now in use lift with given increments of pressure, the effect of various forms of coupling devices based on the pressure between the seat of the valve and the muffler, so as to attain data on which to base a specification providing that a given diameter should have a lift of not less than a certain amount to the given increment of pressure between the seat, that there should be not more than a certain amount of pressure between seat and muffler device, that the area through the muffling device should have a certain proportion to the area of the valve.

Stirling Boiler Company: Mr. Fred Scheffler refers to the formula on p. 9, 1910 catalogue of consolidated safety valve, with 45 degrees beveled seat and actual evaporation tests. Also states that complete data can be obtained from Consolidated Safety Valve Company and the Naval Experimental Station, Annapolis, Md. He favors composition seats with twenty-five per cent metal. Regarding deterioration, he states that a well-designed spring should not lose temper under saturated steam, and that an exposed spring should be used under superheated steam. Very complete information has been published by the Consolidated Safety Valve Company in their book entitled Safety Valve Capacity.

Heine Safety Boiler Company: Col. E. D. Meier writes that experimental data are mainly in the possession of various firms and companies which manufacture high class valves, and cites the Consolidated Company, the Ashcroft Company and the Ashton Company, who have recently installed a boiler suitable for 400 lb. pressure for continuing such experiments. He states that the rules promulgated by various officials and societies seem to be based on experiments made at lower pressure than current practice. These rules may be deficient because action of metals under higher stresses and higher temperature will be different than in the early experiments. Mr. Geo. H. Musgrave has had some experience as a pioneer and is an enthusiast on the subject. There is great need of experimental work and the only safe way for a scientific settlement of these questions would be tests on entirely neutral grounds, i.e., in the laboratory of some well equipped mechanical engineering school of high repute. His company has to conform to three different rules: the regulations of the Board of Supervising Inspectors of Steam Vessels; the Philadelphia Boiler Law; the Boiler Rules of Massachusetts. They give different dimensions so designers are guided by the locality where the boiler is to be operated. An important question is the limit in size, that is, when it becomes necessary to put two or even three safety valves on a boiler in place of one. The amount of lift has a bearing on this.

It may be deduced from the above correspondence that what is needed in determining a method of rating valves is not so much research as it is standardization of practice, defined by recommendations having the weight of the Society behind them. For example, the testimony seems to show that valves having low lift and high lift are operative, and that advocates of both are to be found among people well qualified to pass opinions on the operation of valves in service. It may be that lift is a factor which, while hitherto regarded as of importance, may be neglected, and that its effect will be entirely absorbed in any arrangement which will secure a rating of valves in accordance with their discharge capacity. This and other general questions which have been developed by its inquiry will be considered at a formal meeting of the Committee to be held at the time of the next annual meeting of the Society, at which time it should be possible to take the next step in the development of the Committee's work.

Respectfully submitted,

W. F. M. Goss, *Chairman*
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Research Committee

MODERN SHOE MANUFACTURE

By M. B. Kaven, Beverly, Mass.

Member of the Society

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Non-Member

Some of the earliest forms of foot-wear of which we have any definite knowledge had soles made of various materials, such as wood, fibre and leather, fastened to the feet by thongs or straps. Other forms consisted of mere blocks of wood with holes in which to incase the feet.

2 A somewhat improved form of foot-wear was made by nailing leather uppers to wooden soles and such shoes were often shod with iron to protect them from wear.

3 A greater amount of ingenuity and skill was shown in making shoes from pieces of leather, cut to predetermined shapes and sizes, which were sewed together by hand. This latter method probably led to the invention of the shoe last, which is a wooden block conforming to the desired shape of the shoe, and over which the uppers are molded or lasted during the process of manufacture.

4 The most perfect shoe devised by artisans of this ancient craft, previous to the introduction of shoe machinery, is undoubtedly that known to a few of this generation and to many of the past generation as a hand-sewed shoe.

5 The method of making this shoe consists in first cutting and then sewing together the different parts of the upper; next, shaping the insole to the required form and cutting in its under surface near the edge a shoulder and channel to form a rib to which the upper is sewed. The insole (see Fig. 1) is then secured to the bottom of the

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[1] United Shoe Machinery Company.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

last, the upper being drawn over the last and edge of the insole and temporarily secured to the insole with lasting tacks. With a sharp curved awl the workman makes a hole at the breast of the heel-seat through the rib of the insole and upper and the edge of a narrow strip of flexible leather called a welt, which is sewed to the outside of the upper along the edge of the last to which the outsole is later secured (see Fig. 2).

6 One end of a waxed thread about 5 ft. in length is inserted in the hole made with the awl and drawn through a distance equal to one-half the length of the thread. Another hole is then made through the materials at a distance of about $\frac{3}{8}$ in. in advance of the first hole, and the two ends of the thread are inserted in this second hole from opposite sides and drawn through tight, thereby uniting the welt, upper and insole at that point, and forming the first stitch of the inseam. These operations are repeated until the seam has been sewed completely around the forepart of the shoe, terminating at the breast of the heel upon the opposite side. The lasting tacks are withdrawn, the surplus leather below the inseam trimmed off, and the welt beat out flat.

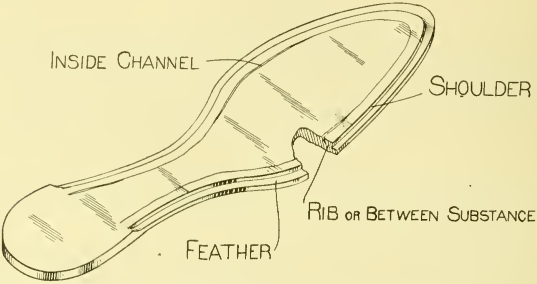

FIG. 1 INSOLE FOR HAND SEWED SHOE

7 The outsole is then cut to the required size and temporarily secured to the bottom of the last, after which it is sewed to the welt, the seam being placed a short distance in from the edge and following the contour of the sole. The stitches of this seam are made much shorter than those of the inseam and for that reason the operation is necessarily slow and requires great skill.

8 The heel is built upon the heel seat of the shoe by nailing to it

layers of leather until the proper height has been obtained after which it is trimmed to the required shape.

9 As the principal operations in the process of making a hand-sewed shoe have been described, the subsequent finishing operations will not be explained.

10 Fifty years ago the size of the average shoe shop would not have measured more than 12 by 15 ft., nor would the average number of men employed in each shop have exceeded three persons. Each workman was taught the whole trade and was often required to select and cut his own stock and make a complete shoe. The tools employed were all hand implements, even the grindstone used to sharpen the cutting tools being turned by hand.

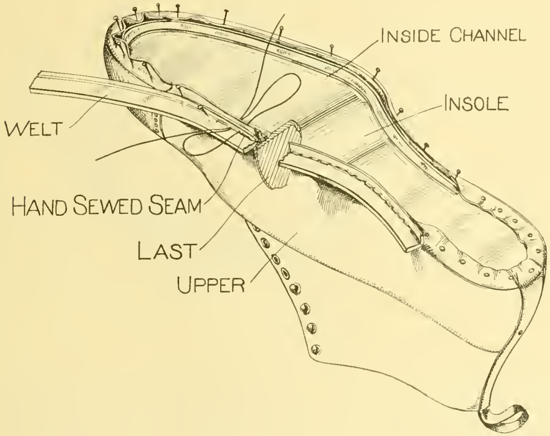

Fig. 2 Hand Sewed Shoe

11 About this period men with inventive minds began to devise means for performing with machinery many of the operations in the making of shoes which were being done by hand, and their efforts were attended with marked success. The most important machine developed during that period was undoubtedly the McKay sewing machine, which united the outsole to the insole by a chain-stitch seam passing through these two soles and leaving a portion of the seam exposed upon the inside of the shoe (Fig. 3). It was therefore necessary

to insert in the shoe a secondary insole or sock-lining to prevent the seam from hurting the feet.

12 Other machines built for fastening soles to shoes perhaps required as great mechanical ability to perfect but were of less importance commercially. Among them was the pegging machine which automatically cut pegs from a strip of wood and drove them through the outsole into the insole, thereby fastening the sole. The ends of the pegs projected through the insole and made it necessary to cut them off before the shoes could be worn.

13 The screw machine was also used to some extent. It screwed a portion of a threaded wire through the outsole into the insole and then severed the wire at the tread surface of the sole, thus automatically cutting the wire screw the exact length of the thickness of the substance it penetrated.

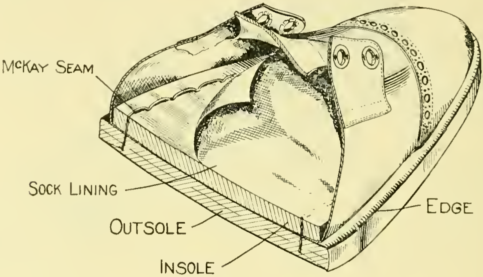

Fig. 3 McKay Shoe

14 The loose-nailing machine drove nails by a hammer blow through the outsole and insole and clinched them upon the inside of the shoe by driving the ends against an anvil set in the end of a horn shaped to enter the shoe.

15 In order to use these different machines it was necessary first to last the shoe, tack on the outsole and then withdraw the last in order to permit the horn to be inserted during the sole-fastening operation. The greatest defect in shoes made by the aid of these machines was that the different fastening materials penetrated the tread surface of the insoles and often roughened them to such an extent as to cause discomfort to the wearer.

16 Machines were invented for performing many operations pre-

viously done by hand but the paramount object was to produce machinery for making shoes by the hand-sewed method, since such shoes when finished contain insoles which are perfectly smooth upon the inside of the shoe, and since they are more flexible than those made on the machines previously mentioned.

17 Inventors spent much time and money in attempting to perfect machinery for making shoes by this method, a result finally achieved through the efforts of Mr. Charles Goodyear. About twenty years ago the Goodyear Shoe Machinery Company placed upon the market a practical inseam sewing machine an and outsole stitcher. Since that time these two machines have been greatly improved upon and hundreds of them are now in daily use in many parts of the world.

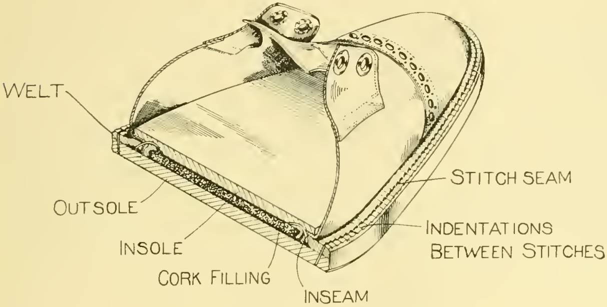

Fig. 4 Goodyear Welt Shoe

18 The introduction of machinery for making Goodyear welt shoes (Fig. 4) revolutionized the industry. The small shops have been superseded by large shoe factories in which thousands of pairs of shoes are made each working day. Where formerly one man made the complete shoe, it is now worked upon by more than 100 different operatives, and more than 60 different machines are used in the process.

THE MODERN SHOE FACTORY

19 As the Goodyear welt shoe represents the highest type of footwear in appearance, comfort and wear that has as yet been produced,

a description will be given of a modern shoe factory, the methods employed and the machinery used in the process of making them.

20 A modern shoe factory is, as a rule, a well-made, four-story building, well-lighted, and equipped with the latest sanitary arrangements for protecting as far as possible the health of the workmen. The power plant is installed in a one-story building outside the main building midway its length.

21 Steam is generally used to generate power and furnish heat electricity for lighting purposes; and the automatic sprinkler system to protect the building and contents from fire. The factory is also equipped with the automatic fire alarm, and with elevators, suitable stairways and fire escapes.

22 An exhaust fan system is used to extract the dust and dirt from the different departments in which abrasive and trimming machines are used. This dirt is conveyed to a receptacle near the power house from which it is taken and burned under the boilers.

23 The first floor is divided into a sole-leather stock room and a sole-leather cutting room; the general offices, the finishing room, treeing and dressing room, and the packing and shipping room are located upon the second floor; and the entire third floor is used as a making room. The fourth floor is divided into the upper-leather stock room, the upper-leather cutting room and the stitching room.

MACHINES AND OPERATIONS

24 When orders are received at the factory, they are recorded in an order book and given a number, and each lot made under that order is designated by a case number. Tags bearing order numbers, together with the details affecting the preparation of the stock, are sent to the cutting and sole leather rooms. Work sheets are daily sent to all of the different departments designating the work required of each for that day.

25 The first operations in the making of shoes, which consist of cutting the upper leather and linings into the required shapes and sizes, are performed in the cutting room. Formerly all such operations were done by hand by workmen who laid patterns upon the leather and then drew a sharp knife along their edges, thereby cutting the leather to conform to them; but to-day this work is done upon a clicking machine, provided with a cutting board very similar to those used by the hand workmen. Extending above the cutting board is

a beam which can be swung over any portion of the board and which is secured to a vertical shaft connected at one end by an eccentric strap surrounding an eccentric upon the driving shaft of the machine. The eccentric shaft is driven by a single revolution clutch to impart to the beam a predetermined downward and upward movement.

26 The skin to be cut is laid upon the board and the operator places a die upon it. Grasping a handle, which is connected to the beam, he causes the latter to swing over the die and by a downward pressure of the handle causes the clutch to operate so as to bring the beam downward and press the die through the leather. As soon as this is accomplished the beam returns to its full height and is automatically swung sideways from over the die.

27 The dies used are but $\frac{3}{4}$ in. in height and of very light weight. The tops of these dies are left open and the opening is substantially the same size and contour as the pieces of leather cut with them, thus enabling the operator to see clearly the entire surface of the leather he is cutting out. It is obvious that pieces of leather cut with any given die must be identically the same in shape. After the different parts required for each lot have been cut, they are tied in separate bundles and the lot number marked upon the top piece in each.

28 The edges of the parts which show on the finished shoe, such as vamps, tips, quarters, etc., must be skived with either a shoulder or beveled edge upon the flesh side. This work is generally performed by a skiving machine, by which the edge of the piece of leather to be skived is fed by feed rolls and held by peculiarly shaped guides against the edge of a sharp revolving disc which cuts the edge to the desired bevel, irrespective of the curves and angles in the edge of the piece of leather operated upon.

29 The pieces which have been skived are fed through a machine which deposits an even coating of cement upon the skived surfaces. After the cement has dried to the proper degree the skived edges are folded upon a folding machine, which turns back the edge about $\frac{3}{16}$ in. and folds it down upon the balance of the skived portion.

30 It will be observed that when the edges of leather having a grain surface have been skived, cemented and folded in the manner described, they will present a very even, smooth and finished appearance. It may be well to add that the folding machine is provided with a knife for cutting slits in that portion of the edge which is folded over in order to make such leather lie down smoothly when folding curved edges.

31 The ornamental perforations cut along the edge of the toe

cap are generally made by a power press, fitted with a die containing a multiplicity of punches for cutting all the perforations simultaneously. It is necessary to use a stripper plate with such dies in order to withdraw the punches from the leather. The punches, which are hollow, cut against a paper band supported by the bed of the machine. A portion of the band is fed after each perforation, in order that a new surface may come under the die for the next cutting. This method insures perfect work.

32 Another form of perforating machine is one used for long and irregular curved pieces. It is provided with a spindle which carries one or more small tools to perforate the work and feed it a predetermined distance. These operations are repeated until the work has been perforated the required distance.

33 On one of the top linings of each shoe is stamped the case number, width and size, by a special stamping machine made for the purpose.

34 After all parts of the upper have been prepared in accordance with the instructions on the tag for this department, and assembled, they are forwarded to the stitching room. Here the different parts of the upper are united.

35 The stitchers, the majority of whom are women, are divided into different classes, and while the lining stitchers are making the various styles of linings, others are at work stitching tips to vamps, ornamenting tops with fancy stitching, closing backs of vamps and tops and back-staying the same, working button holes on the buttonhole machine, and performing other operations according to the style of shoe manufactured. When the tops and vamps have been made ready, they are stitched together on a cylinder vamping machine, an operation requiring skill and accuracy as the success of the future making of the shoe depends greatly upon the work of the vamper. In the stitching room are performed many other minor operations, such as cementing, rubbing seams, strap making, etc., all of which require deftness and dexterity.

36 In this room is also used the duplex eyeletting machine, which eyelets both sides of the shoe at one time with bewildering rapidity.

37 The next and last operation performed in this department is the lacing of the upper upon the lacing machine, which passes strong twine through the eyelets, lacing five pairs and tying the two ends of the twine together at a single revolution. This is done so that all parts of the shoe upper will be held in their normal position while the shoe is being made.

38 With the completion of this operation the preparation of the shoe upper is finished and the different lots with their tags sent to the making or bottoming room; there to meet the different sole leather portions, which in the meantime have been prepared in the sole leather room in accordance with the instructions written upon the tags.

39 The outsoles are cut from sides of leather on large dieing-out machines, which press heavy dies through the leather, or are roughly cut from strips of leather on a block sole cutting machine. The heavy firm portions of the hide which will bear the greatest amount of wear are used for outsoles and top lifts of heels, while the coarser and more flexible portions are used for insoles, taps, counters, toe boxes, welting and heel lifts. These outsoles are fed through a rolling machine where they are subjected to many tons of pressure between heavy rolls, to solidify the leather and increase the wear; and are then fed through a splitting machine which reduces them to an absolutely even thickness. The shank portions are reduced on a skiving machine in order to give the edges a better appearance in the finished shoe.

40 The insoles are trimmed to an exact size on a rounding machine in which the roughly died-out pieces of leather are held between clamps, one of which is the exact pattern of the sole. The pattern and sole are held in a stationary position, while the knife which trims the sole is secured to a yielding carrier completely encircling the sole, and the cutting edge of the knife follows the contour of the pattern. They are then fed through the channeling machine, provided with two knives, one of which cuts a slit along the edge of the insole, and the other a channel in the flesh surface a short distance in from the edge. A lip turning machine is used to turn the lips over against the flesh surface of the insole to form a shoulder, against which the upper is lasted, and to which the upper and welt are later sewed.

41 The toe boxes and counters are cut with dies to the required sizes and skived on a special skiving machine which reduces their edges to a knife-edge thickness. The object of so shaping them is to prevent their edges from forming lines which otherwise would show in the finished shoe.

42 The heels to be used upon these shoes are formed of different lifts of leather cemented and nailed together in a heel-building machine, and placed in layers in a press, subjected to sufficient pressure to hold them flat until the cement sets or hardens. The top lifts, which are later attached to the heel, are compressed in a special machine under many tons of pressure to solidify them, thus greatly increasing their wearing qualities.

43 The first work in the bottoming room is the selection of the lasts required for each lot of shoes, after which the insoles are automatically tacked to the bottoms of the lasts by means of the insole tacking machine. It is necessary to bevel slightly the edges of the heel-seats of the insoles after tacking, to conform to the curves of the last. This operation is preformed by a recently invented machine, provided with a rotary cutter and novel guiding means.

44 The toe box or stiffening is now pasted between the toe tip and the lining of the upper and the counter placed between the heel portion and lining. The last is placed inside the upper and put upon the spindle of the assembling machine, which drives a tack in the back of it to bring the heel portion of the upper and counter into position, and folds a portion of the counter and upper over the edge of the last and insole, securing them by an additional tack.

45 The upper in this condition upon the last is passed to the operator of the pulling-over machine. This is one of the most important machines in the process of making shoes, for the parts of the shoe upper have been cut to conform exactly to the shape of the last, on which they must be correctly placed to secure the desired results. The pincers of the machine grasp the leather at different points on each side of the toe; and the operator, standing where he can see when the upper is exactly centered, presses a foot lever causing the pincers to close and draw the leather securely against the wood of the last. At this point the operator stops the machine and by moving different hand levers which control the pincers he is able to adjust accurately each part of the shoe upper to the position intended for it. The foot lever again being pressed, the pincers move towards each other, drawing the leather securely over the last and at the same time automatically driving three tacks on each side and one at the toe, which hold the uppers securely in position.

46 The assembled parts attached to the last are now ready for the lasting process, which is one of the most difficult operations to perform properly, and for which two types of machines are used.

47 The bed type of machine is usually employed to last the toe and heel portions, while the type known as the "hand-method" welt-lasting machine is used to last the sides, although in some instances it is used to last the whole shoe. The former type is provided with a series of wipers which draw the leather from all directions over the edge of the insole about the toe and heel portions in a very smooth and efficient manner. Before releasing these wipers, the leather is secured in position upon the last by a piece of fine wire passed about

the toe and secured at each end by tacks, the crimples of the surplus leather preventing it from slipping. The surplus leather crimpled in at the heel is forced smoothly down against the insole and held there by tacks driven by a hand tacking machine, in which there is a constantly renewed supply.

48 The hand-method machine which is used for lasting the sides takes its name from the almost human way in which it performs its work. It draws the leather with pincers, evenly and tightly about the last, and, while held in position, tacks are automatically driven into the last a portion of their length to hold the edge of the upper exactly in place. After the shoe has been lasted it is necessary to keep it in that state for a few hours so that the leather may retain the shape to which it has been stretched.

49 There is also left a surplus amount of leather and lining at the toe and along the sides of the shoe projecting over the edge of the insole which must be removed. This is done by the use of the upper-trimming machine, provided with both a rotary and an oscillating knife which cut very smoothly and evenly.

50 On the heel portion of the shoe, the tacks are driven through the insole and clinched on the iron heel of the last, but elsewhere they are driven only part way in, so that they may afterward be withdrawn and leave the inside of the shoe perfectly smooth. They are removed by the tack pulling and resetting machine, which is provided with a pair of jaws which grasp the tack beneath the head, withdraw it, and then throw it into a tube leading to a receptacle at the back of the machine. This device is also provided with a mechanism for driving special soft wire tacks automatically through the upper and into the rib of the insole, temporarily holding the upper in place during the sewing operation.

51 A narrow groove is cut in the welt a short distance from its edge to receive the thread of the inseam, and the insoles are moistened preparatory to being sewed on the Goodyear welt sewing machine (Fig 6), from which these shoes derive their name. The operation of this machine, as previously stated, consists of sewing the welt and upper to the insole.

52 After the shoe has been sewed, the surplus leather above the inseam is trimmed off by the inseam trimming machine, to permit the outsole to lie flat against the seam. The knife which does this trimming is saucer shaped and runs at a high rate of speed.

53 The ends of the welt are skived to a knife edge, after which it is beaten out on the welt beater, in which a hammer vibrates

very rapidly under a yielding pressure. The welt so treated stands out flat from the edge of the shoe. As it is bent about the toe during the sewing operation, it has a natural tendency to draw more tightly at that place, and this strain is relieved by a knife in the beating machine which cuts diagonal slits in the edge of the welt at that point and is under the control of the operator. The tacks which fasten the insole to the last are now removed by the insole tack-pulling machine, and the bottoms of the shoes are filled with a preparation made of ground cork and rubber cement, which prevents the penetration of moisture in damp weather.

54 A steel shank is tacked to the shank portion of the shoe to support the arch of the foot and to help keep the shoe in shape.

55 The bottom of the shoe and of the welt now receive a coating of rubber cement. This cement is contained in an air-tight tank, so that there is very little waste through evaporation, which when applied by hand is excessive. It is applied by means of a revolving brush, which takes its supply of cement as required and in this way gives an even coating of any desired thickness.

56 The flesh surface of the outsole also receives a coat of rubber cement and is allowed to dry to the required degree, after which it is stuck to the bottom of the prepared shoe by the twin sole-laying machine, which is provided with a rubber pad or mold which has been made to conform to the curves in the sole of the shoe. After placing the shoe on the spindle suspended from the upper part of the machine directly over the rubber mold, the sole with its cemented surface is pressed against the bottom of the shoe, and the operator by pressing a foot lever causes the shoe to descend into the mold. By pressing a second lever, additional pressure is brought to bear, forcing every portion of the sole against the bottom of the shoe and welt. Here it is allowed to remain for a sufficient length of time for the cement to set properly. Meanwhile the sole of another shoe is laid in a similar manner in the duplicate or twin portion of the machine.

57 The next operation is that of trimming the edge of the sole and welt to the shape required. This work is performed on the rough rounding and channeling machine. As it is often desired to have the edge extend further on the outside of the shoe than it does on the inside, and generally to have the shank portion trimmed somewhat closer than the forepart edges, this machine is provided with automatic means for performing such operations. Simultaneously with the rounding operation the machine cuts a channel along the edge of the sole (Fig. 5).

58 After the completion of this operation, the shoe is taken to the loose nailing machine, which drives small nails automatically through the heel-seat of the outsole and insole, clinching them against the iron plate upon the heel of the last, thus securely fastening that portion of the sole. The latest improved type of this machine is capable of driving 1400 nails per min., but the average operator is incapable of operating the machine at much more than one-half its capacity upon many kinds of work.

59 The surplus portion of the sole about the heel-seat is trimmed off on the heel seat-rounding machine. The lip of the channel cut by the rough rounding and channeling machine is turned up by the channel-opening machine, which has a peculiarly shaped revolving tool for the purpose.

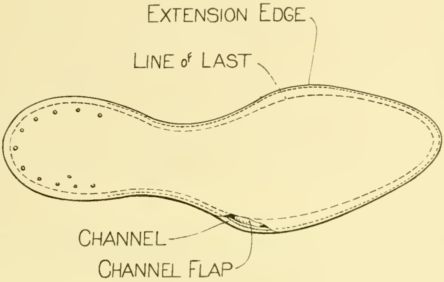

Fig. 5 Outsole of Goodyear Welt Shoe illustrating the relative contour of last and outsole

60 The outsole is now sewed to the welt by the outsole rapid lockstitch machine. The stitched seam extends from the root of the channel cut in the outsole through to the surface of the welt, where the stitches show after the shoe has been finished. This machine, which is fitted with a curved awl and needle to sew with hot waxed thread, is capable of sewing very closely to the upper of the shoe, irrespective of the many curves in the last. It contains a rotary shuttle to carry the bobbin which forms the lockstitch, and is provided with a takeup thread-measuring device, and other suitable thread-handling instrumentalities. The lockstitch seam which it forms is very durable and holds the outsole securely, even after the connecting stitches have worn off.

61 The channel lip of the outsole is now forced into its former position to cover the stitches. By the channel flap-laying machine, in which a rapidly revolving wheel provided with a peculiar arrangement of flanged projections forces the leather smoothly and evenly back into place.

62 The shoe is now ready for the sole leveling operation, which is performed in the automatic sole-leveling machine, so nearly automatic in every particular that all the operator is required to do, apart from the making of adjustments for different styles of shoes, is to jack and unjack them. The machine is provided with two jacks, on one of which the operator places the shoe to be leveled, after which it is passed automatically beneath a vibrating roll under heavy yielding pressure. This roll is controlled by a cam-actuated mechanism which causes the roll to tip so as to level the sole to the required form. At the completion of the leveling operation the jack which supports the shoe is returned to its first position ready for the shoe to be taken from the machine, a shoe having meanwhile been secured upon the second jack and forced forward into the machine to be leveled.

63 The heel of the shoe is now nailed in place by the heeling machine, which performs its work very rapidly and perfectly. The shoe is placed in position on a jack and the heel nails, which have been set in the holes of a plate, are swung into position exactly over the heel and automatically dropped into a die containing holes corresponding to the places where the nails are to be driven. On pressing a foot lever all the nails are driven at one time through the heel, the upper and the insole and are clinched upon the inside of the shoe. The heads are left slightly protruding above the heel so as to retain the toplift which is now placed in position. The operator again presses the foot lever and the machine presses the toplift down over the heads of the nails. This operation is called blind nailing.

64 The shoe is next taken to the slugging machine, which drives short pieces of wire, called "slugs," in and about the edge of the toplift to protect it from wear. This machine will automatically drive and cut from a continuous coil of wire as many as 1000 slugs per minute.

65 The heel is trimmed by the heel-trimming machine, in which a set of very rapidly revolving knives cut away all the rough and surplus portions of leather, leaving the edge of the heel quite smooth and the exact contour intended. Since the toplift is the exact size

of the bottom of the heel, it is used as a guide by the operator when trimming, as is also the edge of the heel-seat of the shoe.

66 The breast of the heel, or that portion which extends over the sole at the shank, is trimmed on the heel-breasting machine. The cut may be made straight across or concave, and with the required slant. The shoe is placed upon the jack of the machine and the tread surface of the heel forced against a plate to support the heel during the descent of the knife, which cuts smoothly through each lift of leather to the exact point at which the heel is joined to the outsole, but without cutting into it. The curve of the knife exactly conforms to the rounded form of the shank portion of the sole.

67 The edges of the heel are now scoured on the heel-scouring machine to make them perfectly smooth and even. This machine has two rolls on which molded sandpaper is fastened, conforming exactly to the contour of the heel. These rolls are driven at a rapid rate of speed, the leather dust scoured from the heels being taken away by the exhaust-fan system previously mentioned.

68 It now becomes necessary to rand or trim away, at a slight bevel, a portion of the surface of the welt outside the line of stitching which fastens the sole to the shoe, in order that subsequent operations in the making of the edge may be properly performed. The beveled portion of the welt is rubbed down hard and smooth to make it retain its shape. These two operations are performed on the trimming and rubbing machine, in the head of which are two shafts which revolve at a high rate of speed. Upon one is mounted a thin beveled cutter, protected at its periphery by a guard to prevent its cutting the stitches of the seam. The second shaft is fitted with a serrated rubbing wheel for rubbing the surface of the welt.

69 Water is now applied by means of a brush to moisten the welt preparatory to separating the stitches, in which operation indentations are made in the leather, crosswise of the welt, in the intervals between the stitches, for the purpose of giving to the surface of the welt an ornamental finish. This work is performed on the stitch-separating machine, and is provided with a feed slide upon which is mounted, by connected mechanism, a tool post to hold the stitch-separating tool. The feed slide has imparted to it a predetermined positive-feeding movement, adjusted to correspond to the longest stitch in the seam to be separated. The tool, however, feeds the work each time a distance equal to the exact length of the stitch separated, whether it be of uniform or of varying length.

70 This result is accomplished by bringing the point of the sep-

arating tool against the surface of the seam with a yielding pressure, and then vibrating the tool lengthwise of the seam to cause its point to enter the interval between the stitches. Further vibrating movement, after the tool has been located in the interval between the stitches, will not move the extreme point of the tool, but instead, the tool holder, to which the tool is fastened and which is held in its normal position by friction, will be rocked about the stud upon which it is mounted. After the completion of the locating movement the tool is forced into the welt a pre-determined distance, with a positive pressure, to separate the stitches and make the required indentation in the welt. This being accomplished, the work is fed the length of the stitch separated. A correcting mechanism moves the tool to its normal position after each feeding movement; otherwise, the machine would fail to accurately locate the intervals between the stitches. It is intended to make the stitches in the seam of equal lengths, but because of the inequalities in the leather and the slight differences in the pressure exerted by the operator while making the seam, the stitches often vary considerably in length, although such variations are hardly perceptible to the eye of the average person.

71 If the machine be set to separate the stitches of a seam containing on an average of 10 stitches to the inch, some individual stitches may be found to average 8 and others 12 to the inch, yet the machine will accurately locate each interval between such stitches, or any length of stitches between the two extremes mentioned. In some instances it is preferred that the stitches be drawn into the welt slightly below its surface. This is termed a fudge stitch, in making which an impression wheel is used to produce a series of indentations on the surface of the welt very similar to those made by the stitch-separating machine.

72 The indentations are afterwards burnished on the burnishing machine. This contains an impression wheel which is free to revolve as the work is fed beneath it, but is positively vibrated lengthwise of the indentations at a high rate of speed to polish them.

73 The edge of the sole is now evenly and smoothly trimmed to the desired shape on the edge-trimming machine, provided with a rapidly revolving cutter for trimming the edge of the fore-part of the shoe, and another slightly different in shape for trimming the edges of the shank portion.

74 After the edges and welt of the shoe have received a coating of special blacking and become sufficiently dry, they are set and burnished on the edge-setting machine. In this, two hot irons, shaped to

fit the trimmed edges, vibrate very rapidly, and the edge of the shoe held against them is quickly set or hardened and given a brilliant and lasting polish.

75 The surface of the top-lift is now made perfectly flat and even on the toplift-sanding machine, the operator holding the surface against the sanded face of a large revolving disc.

76 The breast of the heel is scoured on a small machine fitted with a rapidly revolving cone-shaped disc, surfaced with sandpaper, which brings this portion of the shoe to a proper finish.

77 The edge of the heel is given a coating of special ink on the heel-blacking machine, which contains a reservoir of ink and automatically feeds the amount required to the surface of two brushes revolved in opposite directions. By holding the heel against the brushes the edge is thoroughly and evenly coated with ink, and is finished on the heel-finishing machine.

78 This machine is provided with an iron wheel of peculiar construction made up of a number of segments lying diagonally across its surface and conforming to the varying shapes of heels. Hot wax is automatically conveyed to the surface of the iron wheel, which is also heated. The edge of the heel being held against the wheel, the ink and wax are thoroughly rubbed into the leather, and the heel is then presented to a revolving pad on the machine, which polishes the edge, receiving a final finish by being held against a rapidly revolving brush to give it the required brilliancy.

79 The bottom of the shoe is buffed on the buffing machine, on which two rapidly revolving rolls, covered with sandpaper, remove the outside surface of the grain of the leather for the purpose of adding to the appearance of the bottom when finished. As the shank portions of the sole cannot be properly buffed with these rolls, the buffing machine is used for this purpose. This is an entirely different type of machine. It contains a vertical shaft, upon the lower end of which is mounted a pad of rubber covered with emery cloth revolved many thousand revolutions per minute. An air pump with which the machine is fitted keeps the rubber pad constantly inflated with air, not only keeping the emery cloth cool but adding flexibility to the pad so that it conforms to the surface of the leather being buffed.

80 The bottom and top-lift of the heel are blacked or stained and brought to a highly polished surface on the finishing machine, which has a revolving shaft fitted with different brushes made of cloth or bristles as may be required for the particular kind of work to be performed.

81 Another form of finishing machine known as the stitch and upper cleaner is fitted with special brushes and used for the purpose of polishing the stitches and leather about the indentations in the surface of the welt. It is also used to brush off any dirt which may have accumulated upon the upper of the shoe up to this point in its manufacture.

82 In order that the quality of the shoe may be recognized, a trademark or trade name is generally stamped on the bottom of the sole or in the shank. This work is done by a power stamping machine whereby the operator is enabled to press the heated die against the bottom of the sole under any desired pressure, regulated by hydraulic means.

83 The last, over which the upper was drawn early in the making process, has been allowed to remain in place through all the various operations so that the finished shoe may acquire and retain exactly the shape desired. It is at this point that the last is withdrawn and the shoe placed over the form of the treeing machine. This is the shape of the last, but is collapsible. The pressure of a foot lever in this machine expands the form inside the shoe until it fills it entirely and the operator, using various tools, rubs out every wrinkle that may have made an appearance in the shoe upper and cleans or dresses it with such preparations as will give to the shoe the best appearance. The releasing of the foot lever causes the expanded form to collapse, and the shoe is removed without disturbing in any way its form or finish.

84 The shoe is then inspected and the upper receives its final coat of dressing. Now being finished, it is packed in a carton and made ready for shipment to the purchaser.

WELT-SEWING MACHINE

85 The welt-sewing machine (Fig. 6) is by no means the most complicated in the system of machines for making Goodyear welt shoes, but since it is the most important one, its construction and mode of operation will be briefly described.

86 The head of the machine is mounted upon a post which can be adjusted in a suitable base so as to permit the machine to be set to the height most convenient for operation. The principal parts of the thread-handling mechanism are a curved open-eyed sewing needle, looper, thread finger, takeup, auxiliary-takeup, tension wheel and tension-wheel governing device.

87 The machine has a circular awl for feeding, and a channel guide, both of which are secured to levers mounted upon the feed slide of the machine. It is also provided with a suitable device for holding and guiding the welt, and a back rest to assist in supporting the shoe during the sewing operation. All of these different parts are given their respective movements by levers actuated by a series of cams fastened to the driving shaft of the machine.

88 A steam-heated wax pot attached to the machine holds hot wax to be applied to the sewing thread.

89 The stitch made by this machine is known as a chain-stitch, but is not made by the ordinary method, in which a number of the parts of the machine mentioned could be dispensed with.

90 To sew, it is necessary first to turn the driving shaft to a position that will permit the shoe to be placed in the machine, the end of a strip of leather welting being inserted in the welt guide. The operator takes the shoe by both hands and places it in the machine, pressing it against the point of the awl and of the channel guide at the bottom of the inside channel of the insole at the breast of the heel-seat. By pressing a foot lever, the machine is set in motion, and under the guidance of the operator the welt is sewed to the shoe along the side, around the toe to the breast of the heel-seat upon the opposite side of the shoe, thereby uniting the welt, upper, and insole by a strong, durable, wax-thread seam.

91 To describe a stitch made by this machine, we will presume that a few stitches have already been made in a seam and that there is a loop of thread in the eye of the needle which has been drawn through the work through the previous loop, and which is longer than the required length of a stitch, and that the needle is in its extreme position away from the work with the loop taut in the eye of the needle. Starting the machine at this point, further movement will cause the awl to descend and be forced into the between-substance or rib at the bottom of the inside channel of the insole, when the awl feeds the shoe the length of a stitch to a position which will bring the awl and needle in line. The needle will then descend and be forced through the edge of the welt, upper and between-substance of the insole, going through the hole made in the between-substance by the awl, which during this movement has been withdrawn from the work and out of the path of the needle. During the forward travel of the needle, the loop of thread in the eye will have been forced down upon the shank of the needle by contact with the work. The takeup lever next acts to draw the previous stitch tight,

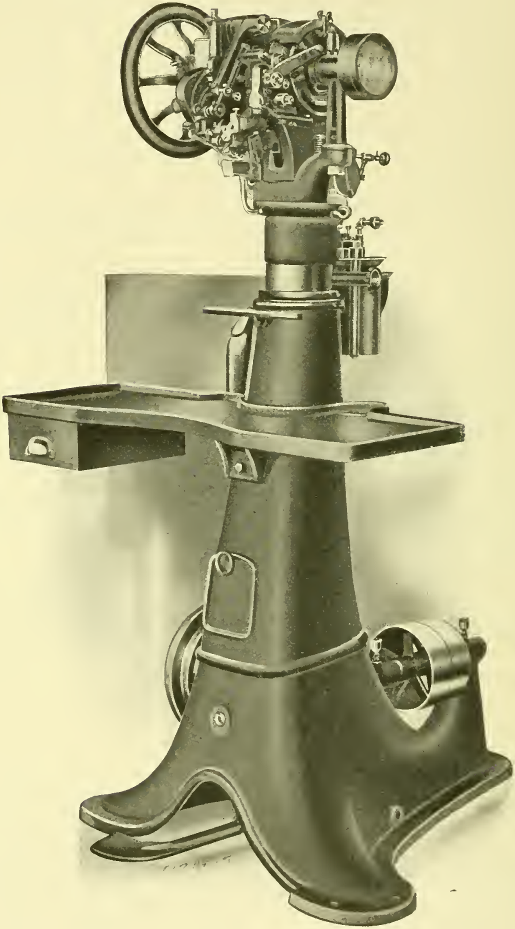

FIG. 6 WELT SEWING MACHINE

taking up the slack thread and pulling the loop tight about the shank of the needle with a strain equal to that exerted by the tension device upon the thread; the continued movement of the takeup drawing an amount of thread from the wax pot or thread supply equal to the amount of thread used in forming the previous stitch. The thread finger now moves to measure off a predetermined amount of the thread taken from the thread supply by the action of the takeup.

92 The looper is next moved in a path about the point of the needle and places the thread in the eye of the needle, the thread being kept taut during such movement by the action of the auxiliary takeup. The needle then acts to pull the new loop of thread through the work, through the previous loop, and to set one leg of the new loop taut against the between-substance of the insole at the root of the channel.

93 The movement of the thread finger should have displaced just enough slack thread to cause the needle to bite the thread at a point in its length which will pull one leg of the loop taut against the between-substance of the insole; shorten the previous loop an amount due to the difference between the area of a cross section of the shank of the needle and the area of two cross sections of the thread of which the loop is made; and pull the new loop taut in the eye of the needle with only a slight reaving movement of the thread through it. A revolution of the camshaft of the machine has now been completed, bringing it to its first position, a stitch having thus been formed in the work by the thread-handling mechanism.

94 The welt is guided about the shoe by the guide locked against the shoe during the time the needle is pulling the thread through the work, and helps to support the work against the pull of the needle. It is again locked against the shoe when the awl is puncturing the insole; and is also given an automatic pullback movement, regulated to a predetermined throw, to allow the shoe to feed clear of the guide and to help draw the welt through it in such a manner as to lay the proper amount of welt around the shoe. It is moved back during the formation of each stitch a uniform distance from the point of contact with the shoe, regardless of the varying thicknesses of the between-subtance to be sewed, so that it is locked at varying distances away from the point of the channel guide.

95 The back rest is locked against the shoe to help support it during the action of the needle and again during the thrust of the awl which punctures the insole.

96 An operator can sew on this machine in a day as many shoes as 100 hand-workmen previously sewed in the same length of time;

and since the sewing thread has been treated with hot wax and pulled by the machine with unvarying tension, the seams are stronger and wear better than those made by hand.

97 The results obtained by the use of the different machines which we have described enables shoe manufacturers at the present time to produce Goodyear welt shoes to retail at prices ranging from \$3.50 to \$7 per pair, which for comfort, style, and superior workmanship, excel those made by custom workmen to sell at prices ranging from \$12 to \$18 per pair.

OPERATING CONDITIONS OF PASSENGER ELEVATORS

By Reginald P. Bolton, New York
Member of the Society

This paper is concerned with the principles that affect and limit the service of passenger elevators, which constitute the most important adjunct to the improvement of real estate and which are continually being more widely used in this connection.

2 The operation of a passenger elevator is unlike that of other reciprocating mechanisms, in that its movements are designedly dependent upon the entrance and exit and the weight of the persons making use of its car. The time during which it is in actual motion is therefore only part of the total time of its service, and it will be manifest that some due proportion of the total time may be expected to be occupied by passenger movement and by machine motion respectively, and should either one or the other be of undue proportion, the result will be a reduction in efficiency, as represented by traffic.

3 Passenger time is that which is consumed while the car is not in motion, but is awaiting the movement of passengers. In schedule service, which is the method of operation universally adopted in business buildings, the period of actual waiting time at the lower floor is limited by the schedule, but in addition to this time, the movement of passengers in entering and leaving the car and the processes of opening and closing the gates occupy a further proportion of the total time of use of the elevator.

4 The period of inaction of an elevator thus has a close relation to the number of passengers carried, and in schedule service the average consumption of time which the writer advanced in a recent work on this subject has been found by experiment to prevail in various cities, indicating that personal characteristics in the use of elevators are very similar in all parts of the country. These allowances are:

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a For each person carried either way .... 5 sec.
b For each person entering at the lower landing...... $1\frac{1}{4}$ sec.
c For each person leaving at lower landing.......... $\frac{3}{4}$ sec.
d For the process of making and leaving the upper landing.................................. 9 sec.

The waiting time at the ground floor, in addition to the foregoing is extended to suit the schedule, which is fixed by the division of the round-trip time between the number of elevators in use. In several tests of the traffic of schedule service, by making the foregoing deductions from the total time occupied, the actual running speed of the elevator car has been correctly predetermined and in others, by deducting the known running time from the total, the foregoing allowances have been substantiated.

5 The machine time is occupied by three main elements:

a Acceleration from a state of rest to designed speed.
b Travel at designed speed.
c Retardation from designed speed to a state of rest.

The average speed of the machine is not its designed or nominal speed, but that which results from the mean time occupied in the foregoing operations. The designed speed may not be attained unless the flight or distance between stops is such that the processes of acceleration and retardation from and to a state of rest do not occupy the entire space of time and distance.

TABLE 1 MEAN SPEED AT VARIOUS FUNCTIONAL DISTANCES

Flight	Functional Distance	
	10 Ft.	15 Ft.
Ft.	Ft. Per Sec.	Ft. Per Sec.
12	4.60	3.73
15	5.00	4.16
18	5.35	4.52
24	5.90	5.13
30	6.33	5.55

6 Fig. 1 shows the course of these functions on a horizontal scale of time and a vertical scale of space, with the mean speeds resulting therefrom. Line AB is that of the designed speed of the car at 500 ft. per min. Curve CD is that of the function of starting and stopping on the up-run within distances respectively of 6 and 4 ft. and $C'D'$ the same operation on the down-run and within a flight from landing to landing of 15 ft. The mean speed is reduced to 5 ft. per

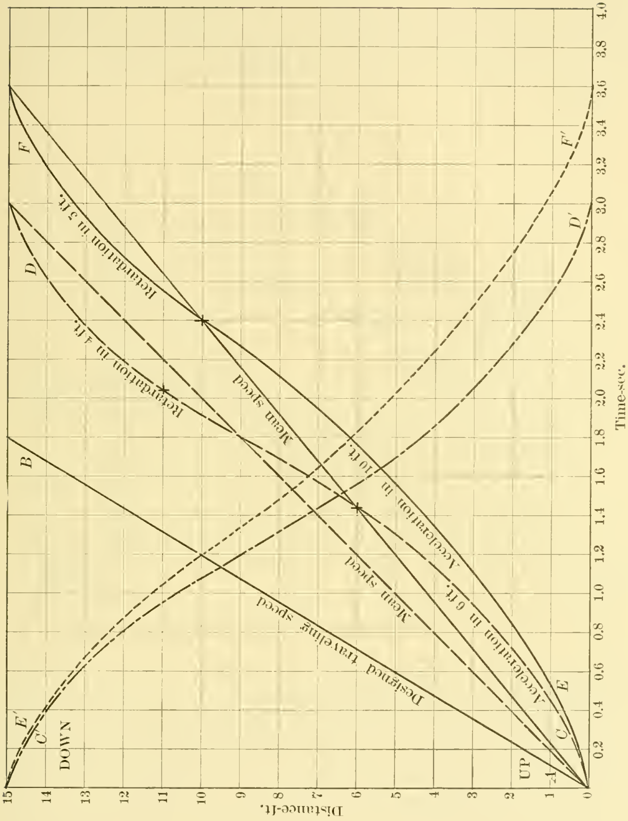

Fig. 1 Speeds at Various Functional Distances

sec., a drop of 40 per cent from the designed speed. Curves *EF* and *E′F′* are those of the same functions exercised in a distance of 10 ft. and 5 ft. respectively, thus occupying the entire space from landing to landing and reducing the mean speed to 4.16 ft. per sec., or 50 per cent of the designed speed. From these and similar curves the mean speeds given in Table 1 have been deduced. In curve *EF* it will be seen that the car on attaining its designed speed, is immediately slackened by the commencement of the process of retardation so that the designed speed is not utilized at any less distance than 15 ft. between landings.

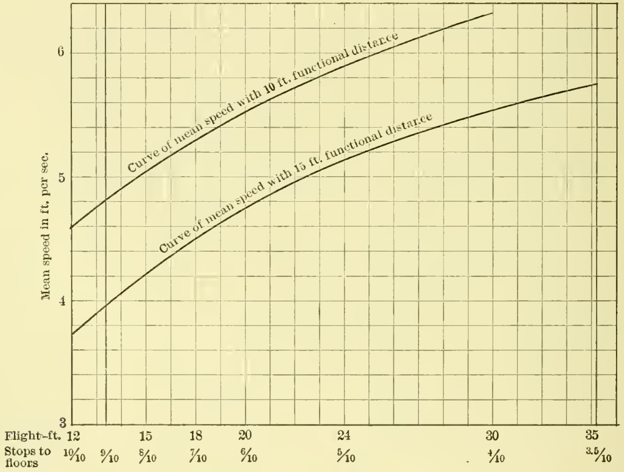

FIG. 2 MEAN SPEEDS BETWEEN LANDINGS AND CORRESPONDING SERVICE

7 Fig. 2 shows these rates of speed at the same two functional distances plotted for all distances between landings from 12 ft. to 35 ft., with the corresponding character of the service expressed in percentage of landings to floors.

8 The gain by the shorter functional distance when making any service is about 12 per cent of machine time, and such an elevator will, if sufficiently powerful for the increased load, attain the same mean speed with $\frac{6}{10}$ traffic as is attained in the other machine with four landings in ten floors.

9 The live load in the car and the weight of the car itself directly affect the functions of acceleration and retardation, aiding or opposing each operation inversely on the up and down runs. Where there is no counterweight or balance applied to the live load, these effects are directly proportioned to the latter. In hydraulic elevators it is not usually practicable to counterbalance the live load, but it is the universal practice to counterbalance some part of the live load in electric elevators, relieving to that extent the two operations in either direction. As electrically operated elevators are now largely in the majority and are constantly on the increase, the relation of the counterbalance to the average live load carried each way appears to be a most important feature and it would be desirable to ascertain it in some definite manner rather than by theoretical assumption.

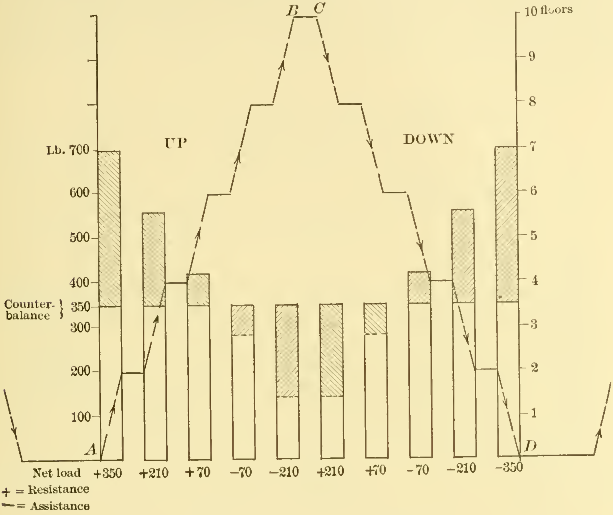

Fig. 3 Effect of Counter Balance

10 Elevator loads are varied on the up and down runs in the manner shown in Fig. 3, in which the flights and stops of a car are shown by line *ABCD* and the weights by the shaded parallelograms. The overbalance, if it be one-half of the commencing and ending live loads, has the theoretical effect of bringing about a complete balance of

lifting and lowering work, and theoretically the net overbalance lifted on the one side is used as descending force on the other. It is due to this feature that the electrical form of elevator will give back a certain amount of motor-generated current to its supply line. The amount so returned is but a portion of that used in lifting the overbalance and is usefully employed only if there be some means of absorbing or utilizing the current. The motor must also be back-rotated to that speed necessary to produce a voltage equal to that of the circuit which is only the case when it has attained its designed speed, so that this economic feature is also dependent on the average distance between stops and starts.

TABLE 2 TESTS AT NIGHT AND DAY BANK BUILDING

AVERAGE LOADS—CAR NO. 2

Hour	Persons Each Way, Average	Live Load, Lb.		
		100–200	200–300	300–400
7– 8	0.75	105	—	—
8– 9	2.09	—	292	—
9–10	2.62	—	—	366
10–11	2.33	—	—	326
11–N	1.91	—	267	—
N–1	2.55	—	—	338
1–2	2.67	—	—	349
2–3	2.65	—	—	347
3–4	1.29	181	—	—
4–5	1.73	—	242	—
5–6	1.67	—	233	—
6–7	0.94	131	—	—
Averages		139	259	345

11 The effect of overbalance is also varied by the fluctuations of the live load in either direction during the hours of traffic, and should this traffic be uneven or such as to vary considerably from the designed relation of load to overbalance, then the benefit of the overbalance is disturbed and its value is considerably impaired.

12 The relation of traffic to counterbalance is therefore a matter of importance, and economy may be effected by ascertaining what proportion the average loads each way bear to the overbalance. These relations may be ascertained after the appliance is in full operation by counting the passengers, but this observation is not of value unless the counting is made of every individual carried each way during some given period of time.

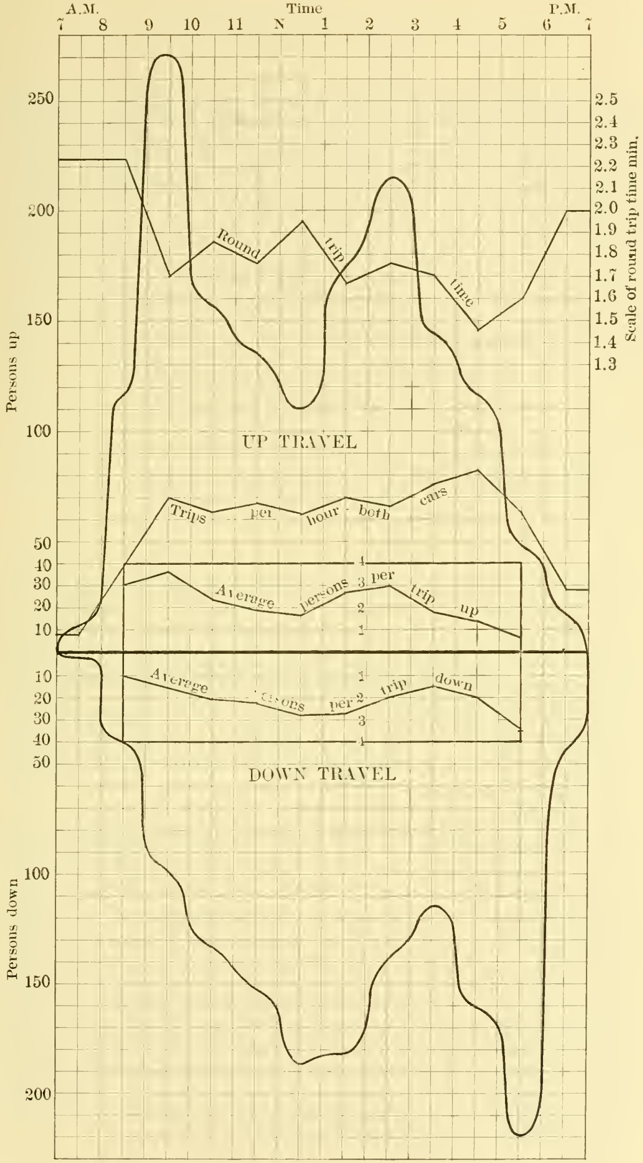

Fig. 4 Elevator Travel in Night and Day Bank Building. New York City

13 The observed operation of the traffic in the cars of the Night and Day Bank Building is shown in Fig. 4, in which are plotted on the vertical scale above and below the middle horizontal line the number of persons carried up and the number of persons carried down on each hour of the business day. This observation shows that the distribution of traffic in such a business and professional building closely coincides with the theoretical distribution advanced by the writer.[1] In the traffic of this building, the heaviest periods of elevator work are from 9 a.m. to 10 a.m. for one-way traffic, and from 2 p.m. to 3 p.m. for two-way traffic, periods which may differ in other cities. The individual work of one car is given in Table 2.

14 The overbalance of these machines is about 800 lb. of live load and is reduced by the weight of the operator to 660 lb. of actual passenger load. The excess or overbalance of the actual mean passenger loads thus becomes 520 lb. for 3 hr., 400 lb. for 4 hr., 310 lb. for 5 hr., indicating that an unnecessary amount of overbalance is provided and that improvement could be effected by reduction of the counterbalance.

15 In hydraulic-cylinder elevators, and notably in those of the plunger type, the absence of counterbalance of the live load not only varies the period of acceleration and retardation to a wide extent, but as the power applied to these machines is fixed in extent, successive increments of load also vary the traveling speed. On a test of the very powerful hydraulic-cylinder elevators of the Hanover Bank Building, the traveling speed both up and down varied from 880 ft. per min. with a live load of 550 lb. to 330 ft. per min. with a live load of 3300 lb. The characteristics of the functions of stopping and starting varied as shown in Table 3.

16 In the plunger type of machine, the effects just described are increased on account of the large mass of material and water which must be set in motion to and arrested from the same speed as the car and the result is that both the period and the distance of acceleration and retardation are relatively prolonged. These effects are largely negatived in the electrical elevator, even where, as in the case of the traction type, the ropes and the counterweight all travel at the car-speed. This result is obtained by the introduction of the electrical and mechanical brake action in retardation, and by the ability of the electric motor to exert force in acceleration and motion approximating the resistance of its load. These capabilities have been very

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[1] Elevator Service, published by the Author.

highly developed in the one-to-one traction electrical elevator, in which motors of large proportions accompany its relatively slow speed and the physical danger of dislodging the cables from the head sheaves by rapid retardation on the up run or of putting excessive strain on the cables in downward retardation are overcome by the arrangement of the friction drive. This form of machine therefore offers the largest possibilities in the directions discussed, affording maximum powers of acceleration at designed speed with all loads, and safe retardation.

17 But even with these powers, it will remain a fact that if the traffic in any elevator be such as to demand a stoppage within a distance less than that occupied by the operations of acceleration and retardation, or what has been described as the functional distance, the designed speed will not be attained. Therefore, unless the number of elevators be so related to the traffic as to afford an average distance between stops in excess of the functional distance, there is no advantage derived from the designed speed. As high rates of designed speed involve proportionate forces, which in each type require either high pressure of power supply or large proportions of apparatus, it will be seen that substantial economy in first cost may be secured by so proportioning the elevators to their work that the best results may be attained with the most moderate designed speed.

TABLE 3 TESTS AT HANOVER BANK BUILDING

Loads, Functional Distances and Speeds

Live Load, Lb.	Speed, Ft. Per Min.	Acceleration Up Retardation Down, Ft.	Retardation Up Acceleration Down, Ft.	Functional Distance. Ft.	Mean Speed in 24 Ft. Per Sec.
3300	330	11	6.6	17.6	2
2200	625	7.25	7.75	15	7.15
1100	800	6.1	12.3	18.4	8.1
550	880	5	24	29	6

18 In all elevators, particularly in those electrically operated, the use of power increases in proportion to the number of starts and stops. This is a natural result of the use of the electric motor, in which the largest part of the energy is required for the process of first motion and acceleration, the next largest for electrical and mechanical retardation, and a lesser amount for the actual running speed, with a small proportion devoted to the continuous excitation of the field. It therefore follows that in this form of elevator, which is now so widely used, the main part of the consumption of power is directly related to the number of stops and starts which accompany and result

from the number of persons carried. The diversities in results which have been reported from time to time as to the consumption of current by electrical elevators may be attributed to variations in traffic conditions.

19 A series of very interesting tests were recently made upon the operation of a one-to-one traction elevator in the ten-story building of the Boston Edison Company, in which observations of the use of current were made at varying numbers of stops and starts with various loads.

TABLE 4 CURRENT CONSUMED BY AN ELECTRIC ELEVATOR AT VARIOUS LOADS AND STOPS

Floors		Up	Bt.–10	1–9	1–9	1–9	1–9
		Down	10–Bt.	9–1	9–1	9–1	9–1
Distance, Ft.		Up	124.6	101.5	101.5	101.5	101.5
		Both Ways	249.2	203	203	203	203
Stops		Up	Bt.–10	1–9	1,5,9	1,3,5.7,9	1,2,3,4,5,6,7,8,9
		Down	10–Bt.	9–1	9,5,1	9,7,5,3,1	9,8,7,6,5,4,3,2,1
		Total	2	2	4	8	16
		Per Mile	42 4	52	104	208	416
Load in Car, Lb.	Operator Only	Kw-Hr. per Car-Mile	2 321	2.181	3.05	2.366	7.95
	666		2.855	2.54	2.51	2 2	6.83
	1060		....	2.2	3.34	4.65	6.8
	2010		....	2.4	3.16	5.0	7.97
	2660		....	2.93	4.16	....	....

Machine: Otis electric traction elevator
Capacity: 2500 lb. at a speed of 500-550 ft. per min.
Balance: 1060 lb.; 200 volts, direct-current
Date of test: December 1909
Place: Boston, Mass.

20 The writer has plotted from these results a series of curves shown in Fig. 5 which indicate very clearly that at all loads an increase in the number of stops results in a progressive increase in the current consumption. The shape of all these curves is affected by the relation of the overbalance to the load and at or near the balance point the most efficient service is naturally attained.

21 In hydraulic elevators the cost in energy of stops and starts is that of the water under pressure, which is used for the reversal of the valves. In a test of the plunger elevators in the United States Express Building, in which the writer took part, the proportion of water thus used in stops and starts was ascertained to be, on the basis of four stops up and four stops down to ten floors above the ground, 11.1 per cent of plunger displacement, and on the basis of a stop at every floor up and down, 22.2 per cent.

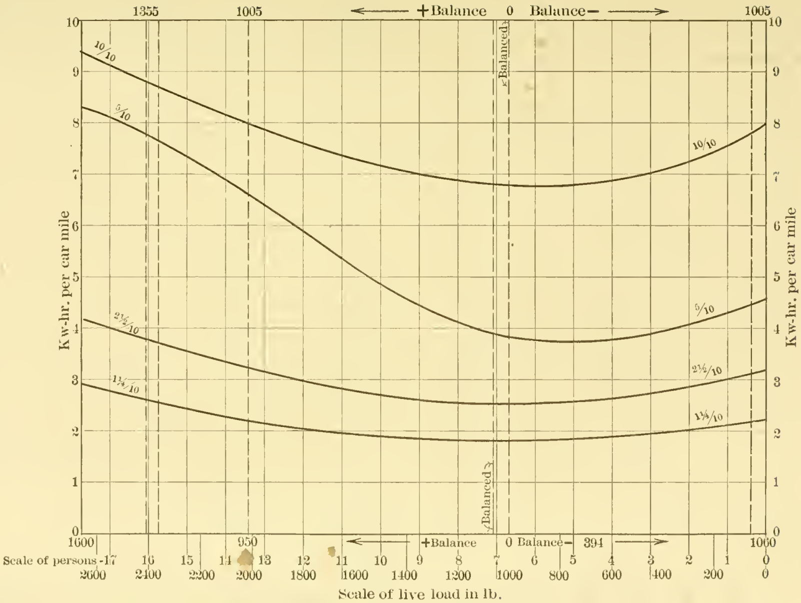


FIG. 5 CURRENT CONSUMPTION OF ELECTRIC ELEVATORS AT VARIOUS LOADS AND STOPS

22 The method employed by the author in securing data bearing on these subjects is the observation of the number of persons carried each way on each trip by each elevator in a given time. Such observations have been taken in a number of buildings of widely differing proportions and characters, in cities as far apart as Seattle and Atlanta,

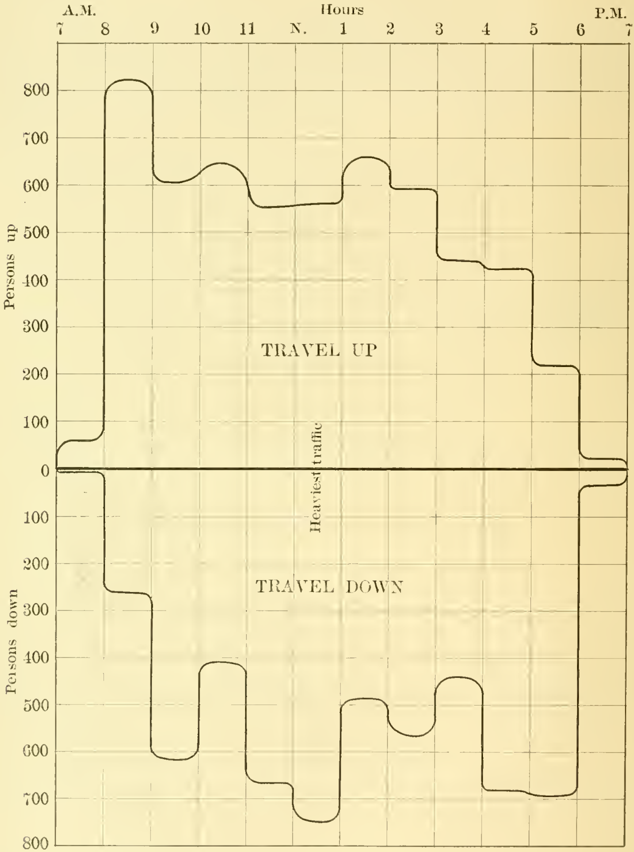
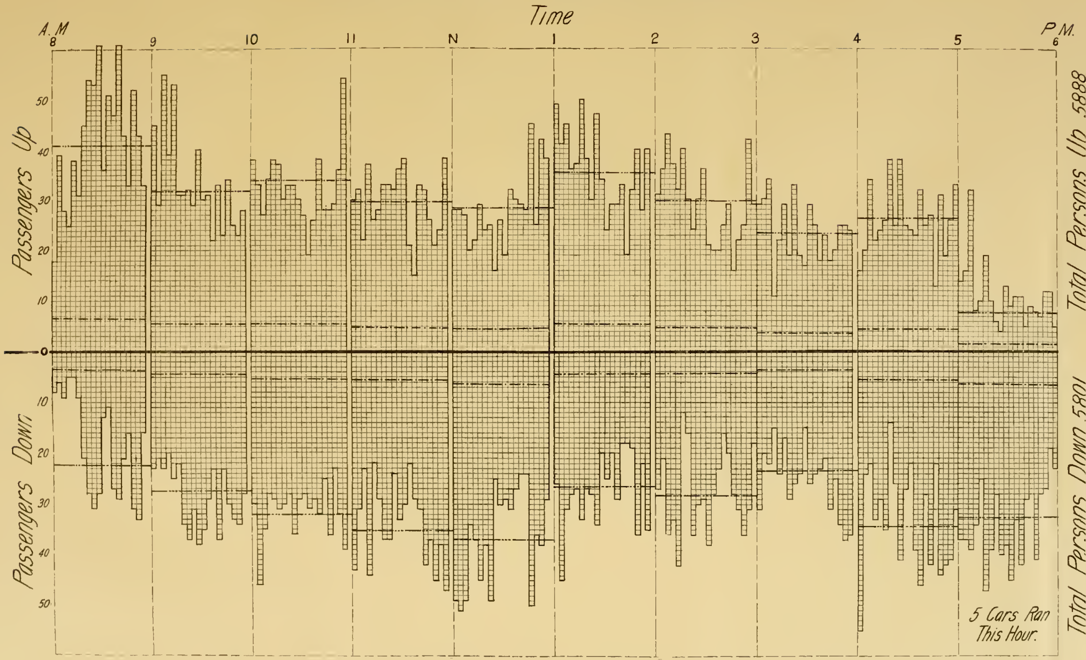


Fig. 6 Flow of Elevator Traffic in a Chicago Office Building

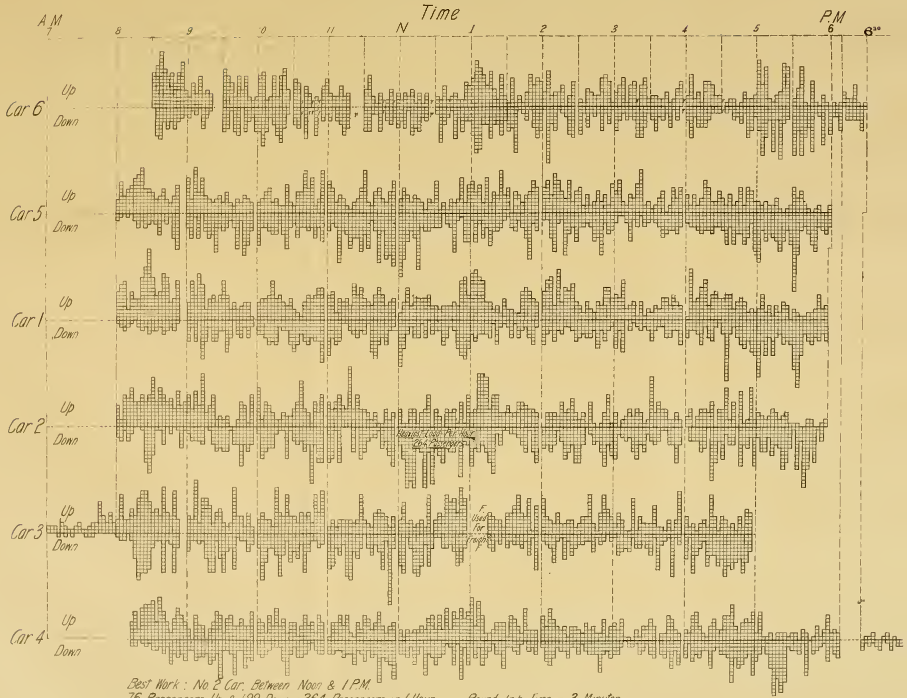
OPERATING CONDITIONS OF PASSENGER ELEVATORS



—··—··—Average Total Six Cars
—·—·—Average Per Hour Per Car
Average Travel Up 5, Down 4.91, Each Way 4.95 Per Car Per Trip

Average Total Each Way Per Hour = 584 Passengers
Average Round Trip Time - 3 Minutes

Fig. 7 Combined Traffic of Six Elevators in a 16-Story Office Building (See Par. 24)



Best Work: No. 2 Car. Between Noon & 1 P.M.
76 Passengers Up & 188 Down = 264 Passengers in 1 Hour. Round Trip Time = 3 Minutes

Fig. 8 Traffic of Individual Elevators in a 16-Story Office Building. (Par. 25).

and as diverse in characteristics as Detroit and Portland, Ore. In all cases these tests have proved of value by indicating opportunities for improvement in service and in economy and have also confirmed the foregoing conclusions as to the influence of traffic upon speed and efficiency of service.

23 An interesting and comprehensive example of this method of observation is that afforded by the six hydraulic elevators of a Chicago office building of 17 stories located in the heart of the business district and having a professional, business and brokerage tenantry. The results of these observations are plotted in diagramatic form in Figs. 6, 7 and 8. The upward and downward traffic is plotted vertically above and below the middle horizontal line and the period of service is shown on the horizontal scale. In Fig. 6 the total combined hourly traffic each way is shown and from it is observable the disposition of traffic during the hours of business, the heaviest period being for one-way traffic from 8 to 9 a.m. and for two-way traffic from noon to 1 p.m. The total combined traffic for the day's service was 5888 persons carried up and 5801 carried down.

24 In Fig. 7 the combined schedule work of the six cars is plotted, showing the number of persons lifted or lowered by all six cars on each schedule movement, affording a picture of the response of schedule operation to the flow of traffic. The average total of the six cars per hour is shown in the double dotted line on the upper and lower part of the scale, and the average number of persons per hour per car is shown in the strong single dotted line. The average number of persons carried per car per hour was 5 up, 4.91 down, and 4.95 each way. The total each way per hour aggregated 584 persons.

25 Fig. 8 shows the work of these cars in still greater detail, the six diagrams giving the individual work of each car per trip, affording a complete picture of the division of the work between the several cars. Several interesting observations can be made from this diagram. The best work of the day was found to have been done by car No. 2, which during the busy hour of noon to 1 p.m. carried 264 persons, or a mean of 6.6 each way per trip. The heaviest day's work was done by car No. 5, which carried an average of 5.34 persons each way in the average round-trip time of 3.07 min. The average round-trip time of the schedule as maintained was 3.09 min., and the best time for an individual car was that of car No. 2 which made certain trips in 2.5 min. round-trip time, carrying 4.35 persons each way, at the rate of 104 persons per hour.

26 It will be observed that at various times the operation of car No. 3 and car No. 6 was interrupted by their diversion from the service for freight purposes, and at the particularly busy time near one o'clock, when this occurrence took place on car No. 3, the traffic was forced into the other cars, the loads on which were greatly increased, with the result that the number of round-trips made by those cars was reduced.

27 The division of passenger time and machine time in these cars was ascertained by observations of the speed of two of the cars with a live load of three passengers each way. On a run from top to bottom of the shaft, the speed developed under those conditions, was 6.77 ft. per sec., corresponding to a designed speed of 400 ft. per min. With the same load, but starting and stopping at every alternate floor, the mean speed fell to 4.8 ft. per sec. As the schedule maintained by the service allowed an interval between arrival and departure of cars at the ground floor of 30.9 sec., the actual time of the average trip became 154.5 sec. The average speed of 4.8 ft. occupies 80 sec., leaving for passenger time, less the top landing, 65.5 sec. The average number of persons carried by two of the cars when operating at this speed was 6.6 each way, or 13.2 in all, so that the passenger time was 5 sec. per passenger per landing, which is the allowance to which reference was previously made.

28 These observations indicated further that the elevators were capable of handling the busy-hour traffic at the rate of four landings to ten floors and were operated under an average of three and one-tenth stops to ten floors, affording an ample service readily capable of meeting the variations in the flow of traffic. They also indicated that during the heaviest period of the day when the relation was increased by the withdrawal of one car, the time of the round trip was delayed and the schedule lengthened, reducing the convenience and the efficiency of the service.

A NEW THEORY OF BELT DRIVING

By Selby Haar,[1] Schenectady, N. Y.

Non-Member

While investigating the subject of belt efficiency the writer found a theory of the transmission of power by leather belting so different from the one generally accepted in the United States that the original purpose of the investigation became of secondary importance. It is not claimed that everything to be presented in this paper is new; in fact, many of the conclusions which will be drawn have already been brought before the Society. It is believed, however, that considerable novelty will be found in many of the opinions cited. Since the accepted theory can be so easily found in reference books, no complete exposition will be attempted here.

2 When a belt is stretched over a pair of pulleys at rest, the tension in both strands is the same, and is due solely to the elasticity of the material. When the pulleys are set in motion and power is transmitted through the belt from one to the other, the tension in the tight side increases while the tension in the slack side decreases, their difference being the so-called "effective pull," which is a measure of the power transmitted. It is known, however, that the sum of the tensions does not remain constant. Since the belt is prevented from sliding on the pulley by virtue of the frictional resistance, a great deal of study has been given to the determination of the coefficient of friction. If T_1 is the gross pull on the tight side, and T_2 the gross pull on the slack side, we obtain the relation $\frac{T_1}{T_2} = e^{f\alpha}$, where e is the base of the natural system of logarithms, f is the coefficient of friction, and α is the circular measure of the smaller arc of contact on the two pulleys. This assumes that f is a constant and that the tension in the belt increases uniformly along the arc of contact; it neglects

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[1] General Electric Company.

The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

also the reduction of the effective tension due to centrifugal force. Since T_1 is limited by the strength of the belt, the effective pull can be increased only by decreasing T_2. If the arc of contact α cannot be changed on account of the diameters or locations of pulleys, the only factor susceptible of variation is f, the coefficient of friction. Most of the familiar methods for increasing the pulling power of a belt depend on an increase, artificial or natural, in the coefficient. It is for this reason that in this country paper and wood pulleys are crowding out iron ones. While $f = 0.4$ is frequently given for leather belts on cast-iron pulleys, $f = 0.65$ is claimed for paper pulleys. Quite a common assumption is that $\frac{T_1}{T_2} = 3$. This brings $f = 0.35$ for $\alpha = 180$ deg., and $f = 0.382$ for $\alpha = 165$ deg. Kent,[1] gives a table based on $f = 0.40$ and $\alpha = 180$ deg., to which is added a table of corrections for other arcs of contact. Several designs for idlers have been developed, which are intended to increase the arc of contact. Furthermore, the introduction of belting made of steel is a step in the direction of increasing T_1. The complete theory makes allowance for the centrifugal force of the belt by reducing the effective tension on both the tight and the loose sides. This counteracting component is $\frac{wv^2}{32.2}$, where w is the weight of a piece of belt 1 ft.long, and 1 in. wide, and v is the belt speed in ft. per sec. The complete expression is

$$\frac{T_1 - \frac{wv^2}{32.2}}{T_2 - \frac{wv^2}{32.2}} = e^{f\alpha},$$

according to which the net allowable tension in the belt decreases as the square of the speed. Fig. 1 shows

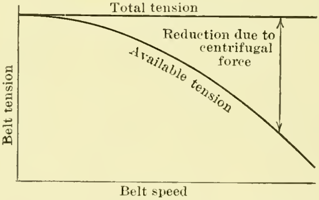

FIG. 1 REDUCTION OF BELT TENSION BY CENTRIFUGAL FORCE

graphically the calculated reduction. So much for the present theory, from which the new theory now diverges.

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[1] Mechanical Engineers' Pocketbook.

3 In 1893, C. Otto Gehrckens[1] published a table of empirical constants derived from experience, giving the effective pull to be allowed in belts, in which the following noteworthy features are contained: the allowable effective pull increases with the speed; at constant speed

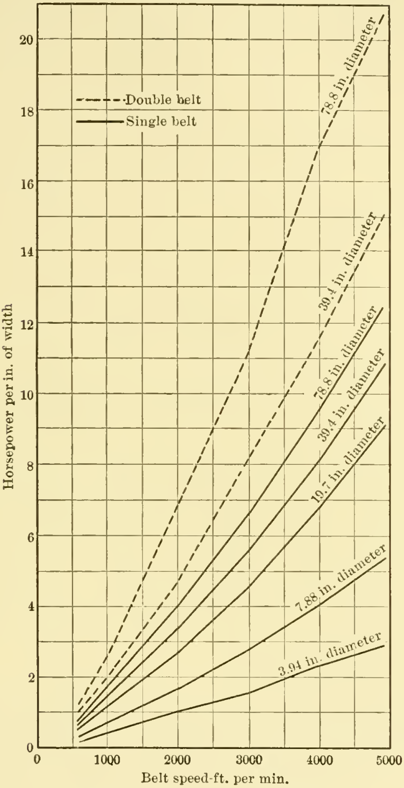

FIG. 2 SAFE LOADS ON BELTS

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[1] Zeitschrift des Vereines deutscher Ingenieure, 1893, p. 15.

the load increases with the diameter of the pulley. Fig. 2, which has been calculated from these constants and converted to English units is inserted to show their general tendency. The curve for a double belt on a 500-mm. (19.7-in.) pulley has been omitted for clearness. The tables and the curves show that a double belt should not be expected to carry twice as much as a single belt. This agrees with our practice.

4 The argument by which Mr. Gehrckens defends these constants is as follows: The leather in the tight side of the belt tends to stretch because of the tension and to contract again when it passes over to the slack side. This successive expansion and contraction occurs in a slowly moving belt, but at high speeds the alternation of position is so rapid that there is not time for the belt to assume a strain corresponding to the stress. As a result the condition of equilibrium is found to be a stretch corresponding to some value of tension less than the actual maximum. The stretch being the limiting condition, the apparent tension in the tight side can be increased with the speed. Professor Bird[1] in his paper on Belt Creep also mentioned this feature of time lag. The larger constants for pulleys of large diameter are explained by the smaller bending stress caused by the curvature. By a series of over 1000 tests on belt transmission, Professor Kammerer[2] of Charlottenburg confirmed this theory completely and Fig. 3 shows his recommendations. This curve is based on $f = 0.5$ and $e^{f\alpha} = 3.5$, from which we deduce that the effective pull is 0.7 of the available tension. It will be noted that even at a speed of 8000 ft. per min. the effective pull has not reached its maximum. His research also included extensive measurements of the coefficient of friction and belt creep, a fuller account of which follows. A description at this point of the testing apparatus may make the discussion of his results clearer.

5 Upon a steel girder base were mounted two heavy cast-iron frames: one, the measuring head, moved on 16 hardened steel balls in grooves so as to reduce friction as much as possible and to compel a movement always truly parallel; and the other, the straining head, rested on a planed surface and was moved by a pair of chains. It was realized that it would be impossible to balance the pulleys perfectly and the frames were purposely made heavy in order to absorb and damp out the vibrations which were expected to occur at high speeds. Each belt-pulley shaft was mounted on two ball bearings to insure reduced and more constant friction and carried at each end the overhung armature of

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[1] Trans. Am.Soc.M.E., vol. 26, p. 584.

[2] Mitteilungen über Forschungsarbeiten, Heft 56–57.

an electric motor. By the use of the two motors the load on the shaft was made symmetrical. This design of the equipment involves the minimum number of bearings with their uncertain friction, and avoids all couplings for transmitting the power.

6 For measuring the belt pull two liquid-pressure dynamometers like those used by Lieutenant Emery were provided, together with a set of pressure gages of suitable ranges. A dynamometer was placed on each side of the pulley on the outer end of the measuring head. Scales and spring dynamometers were rejected because it was feared that the rapid variations of the belt pull would make the readings unsteady. Belt creep was measured by revolution counters attached to the shaft, simultaneous starting and stopping being accomplished by the use of electromagnets, The creep thus measured was the total for both pulleys. The electrical readings consisted of the input to one pair of machines used as motors and the output of the pair on the other shaft used as generators.

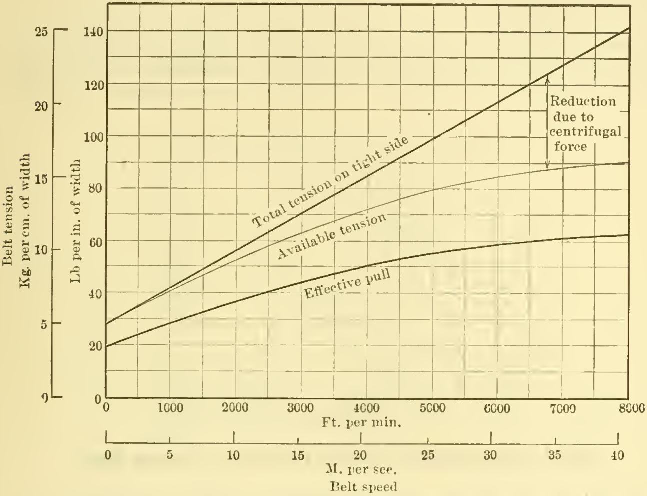

FIG. 3 RECOMMENDED LOADS FOR SINGLE LEATHER BELT

7 The two motors on a shaft were run as a motor-generator set (with belt off the pulley) for the purpose of determining their efficiencies. The dynamometers were calibrated by a standardized tension bar from the Reichsanstalt. This bar was expensive and steel bands attached to the two carriages, loaded in the center and adjusted for constant deflection at the center, were substituted. This method checked well with the other.

8 The following pulleys were used: 2500 mm. (98.5 in.) in diameter and 400 mm. (15.75 in.) wide; 1250 mm. (49.2 in.) in diameter and 600 mm. (23.6 in.

wide; 600 mm. (23.6 in.) in diameter and 1000 mm. (39.4 in.) wide. The distance between centers of pulleys could be adjusted between the limits of 5000 mm. (197 in.) and 7500 mm. (295 in.). Both cast iron and wood were used for the 600-mm. pulleys; all the others were built up of structural steel. Two belts were used for most of the tests: a single belt 375 mm. (14.76) in. wide and 3 to 4 mm. (0.12 to 0.15 in.) thick; and a double belt 400 mm. (15.75) in. wide and 7 to 8 mm. (0.28 to 0.32 in.) thick. The single belt weighed 1.25 kg. per m. (0.84 lb. per ft.) and the double one 2.45 kg. per m. (1.65 lb. per ft.). Both were carefully selected and tanned. The tests with an idler were conducted on a single belt 150 mm. (5.9 in.) wide, 5 mm. (0.2 in.) thick, weighing 0.69 kg. per m. (0.46 lb. per ft.).

9 The modulus of elasticity of each complete belt was measured with the belt on the pulleys and running at a low speed. The tension was read on the dynamometers and the stretch was obtained from the displacement of the straining head. Readings were taken at intervals of two minutes and after each reading the load was reduced to the initial value. The modulus of the single belt increased from 2500 kg. per sq. cm. (35,500 lb. per sq. in.) to 3520 kg. per sq. cm. (50,000 lb. per sq. in.), with an average value of 3000 kg. per sq. cm. (42,600 lb. per sq. in.) (See Fig. 4). The double belt showed an average modulus of elasticity of 2000 kg. per sq. cm. (28,500 lb. per sq. in.). Quite a perceptible permanent set was noticed. The average modulus of elasticity of the third belt was 1250 kg. per cm. (17,800 lb. per sq. in.). Professor Goodman[1] gives 8000 to 10,000 lb. per sq. in. for the modulus and Professor Bird[2] reports 12,000 to 30,000 lb. per sq. in. His comment is that E increases with the tension when the belt is running and is probably larger the greater the speed. Belt speeds varied from 9.56 m. per sec. (1880 ft. per min.) to 60.35 m. per sec. (11,900 ft. per min.). The range of speeds and loads was limited by restricting the tension in the tight side to 30 kg. per sq. cm. (420 lb. per sq. in.).

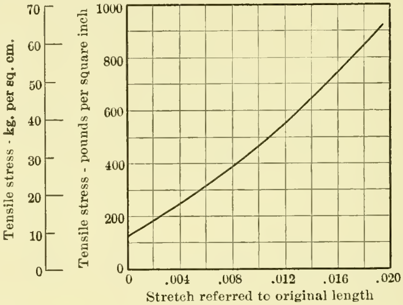

FIG. 4 STRESS-STRAIN DIAGRAM FOR SINGLE LEATHER BELT

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[1] Mechanics Applied to Engineering.

[2] Trans. Am.Soc.M.E., vol. 26, p. 584.

In the light of the knowledge gained from the tests, the future experiments will not be limited by the belt tension, but by a permanent stretch in the belt within 30 min., as indicated by the dynamometer.

10 The following conclusions were drawn from the tests by Prof. Kammerer:

a The effective pull on a belt is not reduced so much by centrifugal force as the currently accepted method of calculation would lead one to expect. In other words, the maximum allowable tension in a belt apparently increases with the speed.

b The coefficient of friction increases with the speed and reaches values far above that usually assumed.

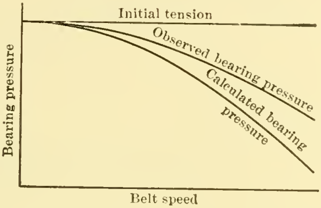

Fig. 5 Effect of Centrifugal Force on a Belt Under Load

c The maximum efficiency of transmission is not limited by the speed.

d The coefficient of friction is larger for large pulleys than for smaller ones.

e A wooden pulley has a higher coefficient of friction than an iron one, at least when new.

f Transmission is more efficient and the coefficient of friction is higher when the smaller pulley drives.

g A belt operates with higher efficiency and usually with less creep when the tight side is on the bottom.

h A properly placed idler improves the efficiency of transmission.

i The neutral layer is symmetrically located in the belt so that the effective diameter is the sum of the pulley diameter and the thickness of the belt.

j At any speed the sum of initial tension and centrifugal force is constant.

11 In connection with conclusion *a*, Fig. 5 is reproduced from Professor Kammerer's report, which confirms the statement previously made. The second method of stating the fact permits of a simpler calculation of the effective pull. It was found that for a single belt a working tension of 5 kg. per cm. (28 lb. per in.) of width at standstill could be increased to 25 kg. per cm. (140 lb. per in.) of width at 40 m. per sec. (7860 ft. per min.). (See Fig. 3). Fig. 6, which is a record of measurements made on the same belt when not transmitting power, shows that the calculated belt pull agrees substantially with the measurements. Professor Kammerer's explanation of this phenomenon (unexpectedly low decrease in bearing pressure) has been sharply criticised by L. Benjamin,[1] who asserts that the reduced belt pull is due to the actual speed of the belt at the pulley being much higher than the average value. He claims that on account of the time lag between the tension and the stretch, the change in stretch resulting from the change in tension as the belt goes around the pulley does not occur until after the belt has left the pulley. The combination of the stretch and the translation of the belt causes a regular

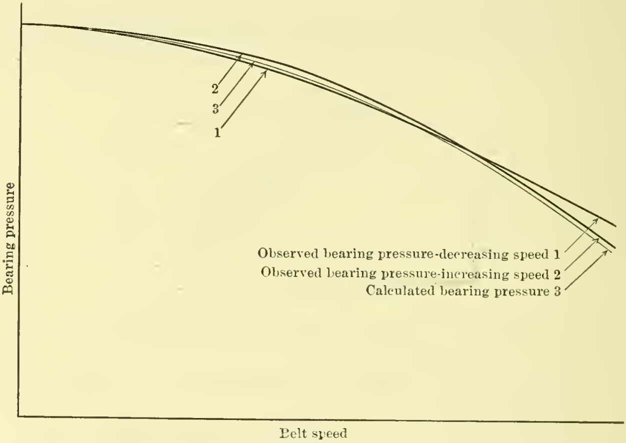

FIG. 6 EFFECT OF CENTRIFUGAL FORCE ON AN UNLOADED BELT

change in its velocity as it travels between the pulleys. This means that the velocity of the tight side as it passes on to the driving pulley is considerably above the average and since the speed is higher, the effective pull must be less.

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[1] Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 655.

12 Alexander Fieber,[1] by means of a tachometer similar to the cut meter, measured the speed at various points along a rubber belt running at an average speed of 5.04 m. per sec. (990 ft. per min.) with a creep of 15 per cent, and an average speed of 5.245 m. per sec. (1030 ft. per min.) with a creep of 5.5 per cent.

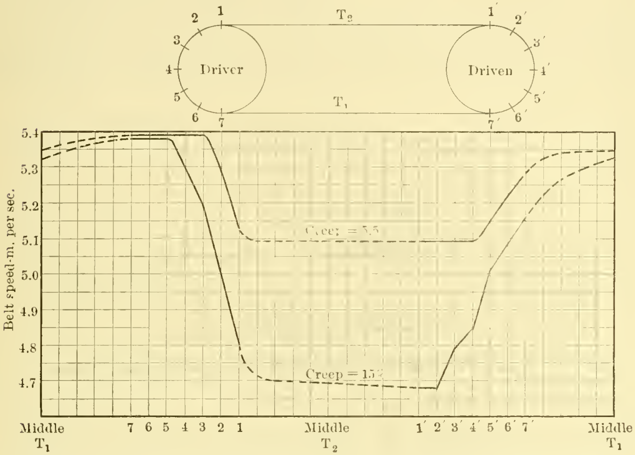

FIG. 7 VARIATION OF SPEED ALONG A BELT TRANSMITTING POWER

The belt was of best Para rubber, 3500 mm. (138 in.) long, 100 mm. (3.94 in.) wide, 6 mm. (0.236 in.) thick. The pulleys were 1700 mm. (67 in.) apart. The average speed was obtained by observing the motion of a chalk mark on the belt. Fig. 7 is a reproduction of these curves, and confirms Mr. Benjamin's contention that the belt speed changes regularly between the pulleys. Professor Kammerer repeated the measurements on a leather belt on pulleys running at 20 m. per sec. (3940 ft. per min.). It was a double belt 90 mm. (3.54 in.) wide, with the tight side on top. The initial tension was 17 kg. per cm. (95 lb. per in.), and the effective pull was 22 kg. per cm. (123 lb. per in.). Both pulleys were 2500 mm. (98.5 in.) in diameter and were 6300 mm. (248 in.) apart. To determine the speeds he used a wheel connected to a revolution counter, which was held at any point for 6 min.

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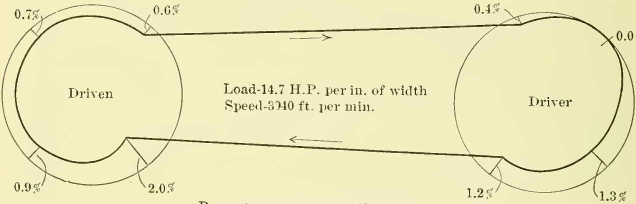
[1] Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 1641.

Fig. 8* shows the measurements he reported. He found that the difference between the speeds of the tight and the loose sides of the belt was only 1.1 per cent, which is quite insufficient to account for the increased capacity observed.

13 The coefficient of friction was calculated from the geometrical arc of contact and the tensions in the belt as deduced from the load and belt pull; this is necessarily an average value, as the formula assumes a regular increase of creep over the whole arc of contact. With arcs of contact of 160 deg. to 175 deg., maximum values of 0.5 to 0.8 were calculated. The value usually assumed, 0.28, should be compared with these, and also 0.35 which was obtained for 10 kg. per cm. (56 lb. per in.) by reducing the load on a slipping belt until the motion stopped, the pulley being stationary. The high values of *f* calculated under certain conditions led to the belief that the continual creep of the belt on the pulley produced a partial vacuum between them. Mr. Gehrckens[1] disagrees with this, however. The coefficient becomes very large when T_2 approaches zero. Mr. Wilfred Lewis has reported values well over 1. Mr. Gehrckens[2] says that at high speeds, say over 50 m. per sec. (9800 ft. per min.) the tension in the slack side can be not only zero, but negative, so that the slack side is not pulled along, but is hurled upon the driven pulley and shoots out over it, as actually happens. The well marked undulation in the slack side is probably started in this way which persists when once started, so that it appears as if the belt were running in the opposite direction from the pulley. For such a case a new formula would have to be developed.



Percentages represent difference between belt and pulley speeds

FIG. 8 VARIATION OF SPEED ALONG A BELT TRANSMITTING POWER

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* Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 1642.

[1] Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 1443.

[2] Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 1820.

14 Mr. Barth[1] gives an expression for f which involves the speed. Professor Kammerer's curves apparently show that f increases with the speed. Another feature influencing the value of f is clearly shown in Fig. 7. This confirms the theory of Grashof that belt creep occurs only on part of the arc of contact, not on the whole of it. The measurements show a part of the pulley circumference over which the belt speed is constant and equal to that of the pulley, while over the rest of the arc of contact the speed changes rapidly. For the same T_1 and T_2, the arc of creep is the same. When the belt is just on the point of slipping off, the arc of creep becomes equal to the arc of contact. E. A. Brauer[2] calls attention to the same phenomenon and says it can easily be shown as a lecture-room experiment. Since different values for f, 0.4 and 0.35, were found for the belt stationary with respect to the pulley, and when slipping over it, the adoption of this assumption would give a still different set of values for f.

15 The efficiency, which should be understood to include the losses in the belt only, was the same at 26.5 m. per sec. (5200 ft. per min.) as at half speed in a certain test. The value 0.98 was reached in each case, but naturally not at the same load.

16 Comparisons of values of the coefficient of friction show that they range a little higher for large pulleys than for smaller ones.

17 American tests confirm the superiority found for wood pulleys but Mr. Gehrckens warns us that belts do not last as long on wood pulleys as on iron. Paper pulleys show a higher coefficient of friction than wood.

18 Differences of over one per cent in efficiency and 0.05 to 0.15 in f were found for the same pulleys and loads, when transmitting from low to high shaft speed or the reverse, the most economical transmission occurring with the higher speed shaft (and smaller pulley) as driver.

19 American practice also calls for the tight side of the belt on the bottom, but the idler is usually not favored. Unquestionably the reverse bending of the belt does not tend to prolong its life, but in some cases the arc of contact can be increased sufficiently so that the effect of the reduced initial tension may counterbalance the depreciating tendency of the reverse bending. The idler used in the tests operated on the slack side of the belt and was carried by a swinging frame which could be screwed down to produce the tension.

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[1] Trans.Am.Soc.M.E., vol. 31, p. 29.

[2] Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 965.

20 The conclusion that the neutral layer of a belt is symmetrically located is generally accepted, although Professor Bach has given $D + \frac{2}{3} S$ as the effective diameter of a driving pulley, and $D + \frac{4}{3} S$ for a driven one (S = thickness of belt).

21 In consequence of the elasticity of the belt, its length and deflection between the pulleys is proportional to the stress which is a resultant of the weight of the belt, the initial tension, and the centrifugal force. The last is, of course, constant for any given speed and causes only a tensile strain in the belt, similar to hoop tension. Now if we construct an expression for the length of the belt, allowing for its stretch, it will be found that the sum of the initial tension and the centrifugal force is constant, as shown by Professor Kammerer.[1] This means that as the speed increases, the initial tension is replaced by tension due to centrifugal force. As the centrifugal stress is absorbed in the belt and produces no bearing pressure, the increase in speed causes a decrease in bearing pressure.

22 Let us return to the efficiency of belt drives, which has been exhaustively discussed by Dr. K. Kobes[2] and by Dr. F. Niethammer,[3] by whom the results of an elaborate method of testing are reported. The losses to be taken into account are due to the stiffness of the belt, creeping on the pulley, thickness of the belt, and friction against the air.

23 *Stiffness.* Assume a belt of width b_1 (in.) and thickness S_1 (in.) running over a driving pulley D_1 (in.) in diameter at n_1 r.p.m., and a driven pulley D_2 (in.) in diameter at n_2 r.p.m. If the driving pulley delivers to the belt N_1 h.p. at a speed V_1 (ft. per min.) $= \pi D_1 n_1$, the effective pull is P_1 (lb.) $= \frac{N_1 \times 33{,}000}{V_1}$ at the pulley rim. The loss due to stiffness was found by Grove[4] to be represented by an expression which reduces in English units to

$$\Delta P_1 = 0.167\, E b_1 S_1 \left[\left(\frac{S_1}{D_1}\right)^2 + \left(\frac{S_1}{D_2}\right)^2 \right]$$

where E is the modulus of elasticity of the leather. This must be reduced to the pulley rim as Dr. Kobes subtracts it directly from

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[1] Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 1820.

[2] Zeitschrift des Oesterreichischen Ingenieure und Architekten-Vereines, 1908, Nos. 16, 47, 48.

[3] Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 668.

[4] Einfache Maschinenteile, p. 263.

P_1. The relative loss is

$$\frac{\Delta P_1}{\frac{N_1 \times 33{,}000}{V_1}} = \frac{\Delta P_1 V_1}{33{,}000\, N_1}$$

and the partial efficiency is $1 - \frac{\Delta P_1 V_1}{33{,}000 N_1}$. Let $\frac{\Delta P_1 V_1}{33{,}000} = a$, then the efficiency is $1 - \frac{a}{N_1}$. Now as long as E and V_1 are constant, a is constant, so that the equation for efficiency is a rectangular hyperbola, according to which the efficiency increases continually with the load.

24 *Creep and Thickness.* Without creep the belt would have a uniform velocity throughout, and the speed of the driven pulley n_2' r.p.m. would be $n_2' = \frac{D_1 + S}{D_2 + S}$. The transmission of power necessarily involves creep, which is proportional to the effective tension on the unit area of cross-section, and the effect of creep is a loss of velocity. If ψ is a constant of proportionality, the ratio of creep to belt velocity is $\psi \frac{N_1 \times 33{,}000}{V_1 b_1 S_1}$ and the actual speed of pulley 2 is

$$n_2 = n_1 \frac{D_1 + S}{D_2 + S}\left(1 - \psi \frac{33{,}000}{V_1 b_1 S_1} N_1\right)$$

If we had also neglected the thickness of the belt, the speed of pulley 2 would have been $n_2'' = n_1 \frac{D_1}{D_2}$. Since there is no loss of pull between pulleys the efficiency is the ratio of actual to theoretical speed, or

$$\frac{n_2}{n_2''} = \frac{n_2}{n_1 \frac{D_1}{D_2}} = \frac{n_2}{n_1} \times \frac{D_2}{D_1} = \frac{D_2}{D_1} \times \frac{D_1 + S}{D_2 + S}\left(1 - \psi \frac{33{,}000}{V_1 b_1 S_1} N_1\right).$$

Now if $b = \frac{D_2}{D_1} \times \frac{D_1 + S}{D_2 + S}$ and $c = \frac{V_1 b_1 S_1}{33{,}000\, \psi}$, the partial efficiency $= b\left(\frac{N_1}{1 - c}\right)$ which is the equation of a straight line. The efficiency therefore deceases directly with the load.

25 *Air Resistance.* According to Zahm,[1] the frictional resistance

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[1] Phil. Mag., 1904, vol. 2, p. 58.

R (lb.) on one side of a plate 1 ft. wide, l ft. long, at a relative air velocity of v ft. per sec. is $R = 0.00000778\, l^{0.93}\, v^{1.85}$. Using l instead of $l^{0.93}$ and taking e as the distance between centers of pulleys we have, for an open belt, a total resistance

$$R = 0.00000778 \left[4\left(b_1 + S_1\right) e + \left(b_1 + 2\, S_1\right)\left(D_1 + D_2\right)\frac{\pi}{2}\right]\left(\frac{V_1}{60}\right)^{1.85}$$

which gives a loss in horsepower of

$$N_a = \frac{0.00000778}{(60)^{2.85} \times 550}\left[4\left(b_1 + S_1\right) e + \left(b_1 + 2\, S_1\right)\left(D_1 + D_2\right)\frac{\pi}{2}\right] V_1^{2.85}$$

This contains only constant quantities when V_1 is constant and hence is independent of the load. When this loss is allowed for the total efficiency is obtained, the curve of which is an hyperbola.

26 The output, being the product of the efficiency and the input, follows an equation which is that of a parabola. If N_2 is the output in horsepower,

$$N_2 = b\left[\left(1 + \frac{a}{c}\right) N_1 - \left(a + \frac{N_a}{b}\right) - \frac{N_1^2}{c}\right]$$

The axis of the parabola is parallel to the output coördinate and passes through the point of maximum output, which has the coördinates $N_1 \text{ max.} = \frac{a + c}{2}$, $N_2 \text{ max.} = \frac{b}{c}\left(\frac{a - c}{2}\right)^2 - N_a$. The curves conform quite closely in general features to motor curves. The same value of output corresponds to two values of input in most cases, and the maximum output occurs at a greater load than the maximum efficiency. The largest component of the losses is the creep, so that the maximum output of a belt would occur at a creep of nearly 50 per cent. Therefore, the maximum output of a leather belt may be said to have no practical significance.

27 The constant ψ which occurs in the expression for the creep was found by test to be $\frac{1}{1100}$ in metric units or $\frac{1}{15{,}700}$ in English units. According to Grashof, $\frac{1}{\psi} = E$ so that tests show ψ twice as large as it should be. Possibly Grashof's formula refers to the creep on one pulley, whereas Professor Kammerer's measurements included both pulleys. Professor Bird gives an equation for creep of the form

$$\frac{\dfrac{P_1}{b_1 s_1}}{E + \dfrac{P_1}{b_1 s_1}} = \frac{V_1 - V_2}{V_1}$$

which is quite similar to the form used above.

28 The writer does not agree with the assumption of a loss due to the thickness of the belt, because it is not clear to him how such a loss would be manifested, whether as heat or in some other way. There is an increase of effective pull at the face of the driven pulley to correspond to the decreased diameter as compared with the belt.

TABLE 1 TEST RESULTS ON BELT EFFICIENCY

Delivered to Belt by Motor		Belt Loss	Efficiency of Belt	Effective Pull per Unit Width*	
Watts	H.p.	Watts		Kg. per Cm.	Lb. per In.
433	0.58	90	0.79	1.12	6.27
1456	1.95	90	0.938	2.91	16.3
2500	3.35	70	0.972	4.86	27.2
3640	4.88	75	0.979	7.07	39.6
4190	5.61	95	0.977	8.19	45.8
4810	6.45	100	0.979	9.56	53.5

*Belt speed at 1100 r.p.m. of generator, 17.3 m. per sec. (3400 ft. per min.)

TABLE 2 TEST RESULTS ON EFFECTIVE PULL

Motor r.p.m., Per Cent Above Generator r.p.m.	Effective Pull	
	Kg. per Cm.	Lb. per In.
2 45	9.7	54.3
1.73	8.0	44.8
1.18	5.44	30.4
0.91	2.9	16.2
0.45	0.8	4.48

29 Professor Niethammer's tests, which have already been mentioned, were carried out in the following manner:

> An electric motor was belted to a dynamo, both having pulleys of the same diameter, and an extended load test was run, the readings being taken with exceeding care. The pulleys were then removed, motor and dynamo were connected by a flexible coupling, and the tests were repeated, particular care being taken that the dynamo potential, current and speed were reproduced exactly as before. It was assumed then that the input to the dynamo was the same in

both tests. The motor was then disconnected and tested with a brake under proper conditions to determine its actual output in both the previous tests, the difference in motor output being taken as the loss in the belt. Two belts were used: one a single belt 30 mm. (1.18 in.) wide, 4.8 mm. (0.19 in.) thick; the other 68 mm. (2.68 in.) wide, otherwise the same. The narrow belt was new. The pulleys were 300 mm. (11.8 in.) in diameter and were 1900 mm. (75 in.) on centers. Table 1 has been prepared from figures given in the paper.

Attention is called to the fact that the belt loss is nearly constant, to the rapid rise of efficiency and to the extended range of the high values. For the sake of completeness Table 2, comprising the creep curve on both pulleys, has been included. This curve does not pass through the origin. Professor Kammerer reports an efficiency of over 0.98 for a speed of 13 m. per sec. (2560 ft. per min.) and an effective pull of about 5 kg. per cm. (28 lb. per in.), while the method developed above gives 97.3 per cent at 7.07 kg. per cm. effective pull. This calculation is given in Appendix No. 1.

30 It should be noted that no allowance is made for the increase in bearing friction due to the belt pull or to the weight of the brake.

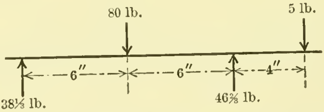

Fig. 9 Loads and Bearing Reactions Due to Weights

That this increased friction may not be inconsiderable will be shown by the following example. Assume a 5-h.p. motor running at 1100 r.p.m. with an armature weight and bearing spacing as shown in Fig. 9. Let the pulley weight be taken as 5 lb. The load on the right-hand bearing is 46⅔ lb. and on the left-hand one 38⅓ lb. With a coefficient of friction of 0.02 and a bearing diameter of 1½ in., the bearing friction is approximately 16 watts. At a belt speed of 3400 ft. per min. the effective pull for 5 h.p. is 48.5 lb. The total belt pull may be taken as twice this, or 97 lb. The bearing reactions are 129⅓ lb. for the right-hand side, and minus 32⅓ for the left-hand side, as shown in Fig. 10. These latter loads are horizontal, while the weights act vertically; therefore they must be combined vectorially. The resultant bearing loads are 137½ lb. and 50 lb. for the right and left-hand bearings respectively. If the coefficient of friction is 0.015, the friction loss is approximately 27 watts, an increase of 11 watts, which occurs in both motor and generator, so that the total increase is 22 watts, which should be noticeable in a loss of 75 to 100 watts.

31 *Conclusion.* As a result of the modern experimental work on power transmission by leather belting, a great deal of light has been shed on the subject and the methods of treating it must be revised. It appears proved that the maximum allowable tension in a belt is not constant and neither is the belt velocity, even though the pulleys revolve at constant speed. The efficiency of a belt is shown to be quite high, just as high as a good gear transmission, the overall efficiency of the belt transmission being considerably reduced by larger bearing friction losses. This shows that the improvements should come in the bearings, as by the use of ball or roller bearings, for example. The exceptional flexibility of a belt transmission has made it a favorite for many difficult problems. We shall close with the following remarkable—and, we are afraid, over-enthusiastic—prophecy of Mr. Gehrckens:[1]

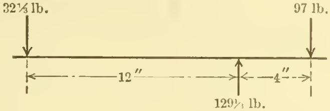

FIG. 10 LOADS AND BEARING REACTIONS DUE TO BELT PULLS

> Sixty m. per sec. (11,900 ft. per min.) is no limit to belt speeds at present. Belt pulleys have run at 500 m. per sec. (98,000 ft. per min.). Brown, Boveri and Company have reached 375 m. per sec. (74,000 ft. per min.); the Schuckert Company run flywheels at 100 m. per sec. (19,600 ft. per min.), (and so do American manufacturers).[2] Air resistance is an important feature at such speeds. When air is excluded the resistance decreases to one-half, and in a vacuum it is almost nothing. * * * We are by no means close to the limit of belt speeds, and the capacity of the belt does not commence to increase until high speeds are reached. Steam turbine speeds are so high that some reducing device must be provided and for this purpose the belt is the simplest and most practical connecting link. With transmissions at such high speeds the construction must be painstaking and the crowning of the pulley is an important feature.

[1] Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 1444.

[2] Parenthetical expression is Mr. Haar's own comment.

APPENDIX NO. 1

CALCULATION OF BELT EFFICIENCY

32 *Example.* A motor delivers 4.88 h.p. to a belt 1.18 in. wide, 0.189 in. thick, running 3450 ft. per min. over pulleys 11.8 in. in diameter and 75 in. apart. The driven pulley makes 1100 r.p.m. What is the efficiency?

$$\Delta P_1 = 0.167 \times 31{,}300 \times 1.18 \times 0.189 \times \left[2 \times \left(\frac{0.189}{11.8} \right)^2 \right] = 0.595 \text{ lb.}$$

$$a = \frac{0.595 \times 3450}{33{,}000} = 0.0621 \text{ h.p.}$$

$$b = 1$$

$$c = \frac{3450 \times 1.18 \times 0.189}{33{,}000 \times \dfrac{1}{15{,}700}} = 366 \text{ h.p.}$$

$$N_a = \frac{0.00000778}{(60)^{2.85} \times 550} \left[\frac{4\,(1.18 + 0.189)}{12} \times 6.25 + \left(\frac{1.18 + 0.378}{12} \right) \left(\frac{11.8 + 11.8}{12} \right) \frac{\pi}{2} \right] (3450)^{2.85} = 0.00476 \text{ h.p.}$$

$$N_2 \text{ (output)} = \left[\left(1 + \frac{0.0621}{366} \right) 4.88 - \left(0.0621 + \frac{0.00476}{1} \right) - \frac{(4.88)^2}{366} \right]$$

$$\text{Efficiency} = \frac{N_2}{N_1} = \frac{N_2}{4.88} = 1 + \frac{0.0621}{366} - \frac{0.0621 + 0.00476}{4.88} - \frac{4.88}{366} = 0.973$$

The loss is about equally divided between creep and stiffness, the air friction being negligible.

APPENDIX NO. 2

REFERENCES

Barth, C. G. Trans. Am.Soc.M.E., Vol. 31, p. 29.

Benjamin, L. Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 655.

Bird, W. W. Trans. Am.Soc.M.E., Vol. 26, p. 584.

Brauer, E. A. Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 965.

Fieber, A. Zeitschrift des Vereines deutscher Ingenieure, 1909, p. 1641.

Gehrckens, C. O. Zeitschrift des Vereines deutscher Ingenieure, 1893, p. 15; 1908, pp. 1443, 1820.

Goodman. Mechanics Applied to Engineering.

Hennig, R. Zeitschrift des Vereines deutscher Ingenieure, 1908, p. 1819.

Kammerer. Mitteilungen über Forschungsarbeiten, Heft 56 and 57.

[illegible] Zeitschrift des Vereines deutscher Ingenieure, Abstract report, 1907, p. 1085; Discussion, 1908 and 1909, several places.

Kobes, K. Zeitschrift des Oesterreichischen Ingenieure und Architekten-Vereines, 1908, Nos. 16, 47, 48.
Revue de Mecanique, June 1909.

Niethammer, F. and Czepek, R. Zeitschrift des Vereines deutcher Ingenieure, 1908, p. 668.

NOTES ON THE VALUE OF NAPIER'S COEFFICIENT WITH SUPERHEATED STEAM

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Associate Member of the Society

Owing to the fact that there do not appear to be any data on the value of Napier's coefficient with superheated steam, the writer is led to submit the results of some incidental observations made during the past year in connection with a series of tests run for a quite different purpose. The values recorded are for superheats between 45 and 195 deg. fahr., but unfortunately the entire series is confined to a quite narrow range of pressures, viz., between 138 and 148 lb. above the atmosphere.

2 The boiler used in these tests was fired with a chain-grate stoker and was fitted with a superheater of a special type, designed so as to conveniently secure various amounts of heating surface with practically constant superheat for each arrangement at a given boiler capacity. Each test was of five hours duration, preceded by a preliminary run of from four to five hours. depending upon the time necessary to bring the various observations to a constant state. A special feed line was used, the main feed being blocked by two valves with an open drain between. The boiler blow-off outlet was visible, and special care was taken to inspect all parts of the boiler before and after each test to make sure that there was no leakage. The water used was measured in two tanks, the contents of which could be read at any level within an error of 0.2 of 1 per cent. The feed water was regulated by a man stationed at the waterglass to within $\frac{1}{2}$ in. of a fixed height at all times and the water level was brought exactly to this fixed point at the close of each hour to secure hourly readings. An error of $\frac{1}{4}$ in. in water level at the close of any of these tests would have caused an error of 0.37 of 1 per cent, and considering the care

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taken, the probable error for any test was less than this amount. That the errors of observation were small is shown by the regularity with which the plotted results compare with an average curve drawn through them.

3 The diaphragm containing the orifice was placed at a short distance beyond the superheated outlet, and immediately below the diaphragm was placed a thermometer well and a connection for a pressure gage. The thermometer used at this point had a scale corrected for stem radiation. The pressure gage was furnished with a scale specially calibrated, and was in addition checked by means of interchange with other similar gages at other points on the boiler and by difference readings taken from time to time during the running of each test. The gages were also tested with a dead-weight apparatus a number of times during the series of tests.

4 The outlet beyond the diaphragm consisted of a fixed length of piping. Pressure readings taken just beyond the diaphragm showed 3 lb. above the atmosphere, an amount entirely negligible with respect to pressures on the high side of the diaphragm, so far as its effect in altering the weight of steam discharged is concerned.

5 The same orifice was used in all the tests. It was formed in a $\frac{1}{2}$-in. plate with edges rounded to a $\frac{1}{4}$-in. radius, the contracted diameter being 1.200 in. In figuring results, no correction was made for expansion due to the temperature of the diaphragm, owing to the smallness of the error arising from this source.

6 The amount of steam for any one test did not vary more than 5 per cent from the average amount of all the tests.

7 The results of these tests are plotted in Fig. 1, in which curve No. 1 shows the Napier coefficient corresponding to each set of the readings obtained in the various tests. Calibration tests of the orifice for saturated steam show a coefficient of about 72.3, the difference between this value and the ordinary figure of 70 being no doubt due to the form of the orifice. Taking the probable water error at 0.2 per cent, the pressure error at 0.4 per cent and the orifice error 0.1 per cent, it will be noted that the total error approximately accounts for the discrepancy in those tests that lie furthest from the average curve.

8 The formula for determining Napier's coefficient as plotted in curve No. 1, is

$$C_1 = \frac{pa}{W} \qquad \text{[1]}$$

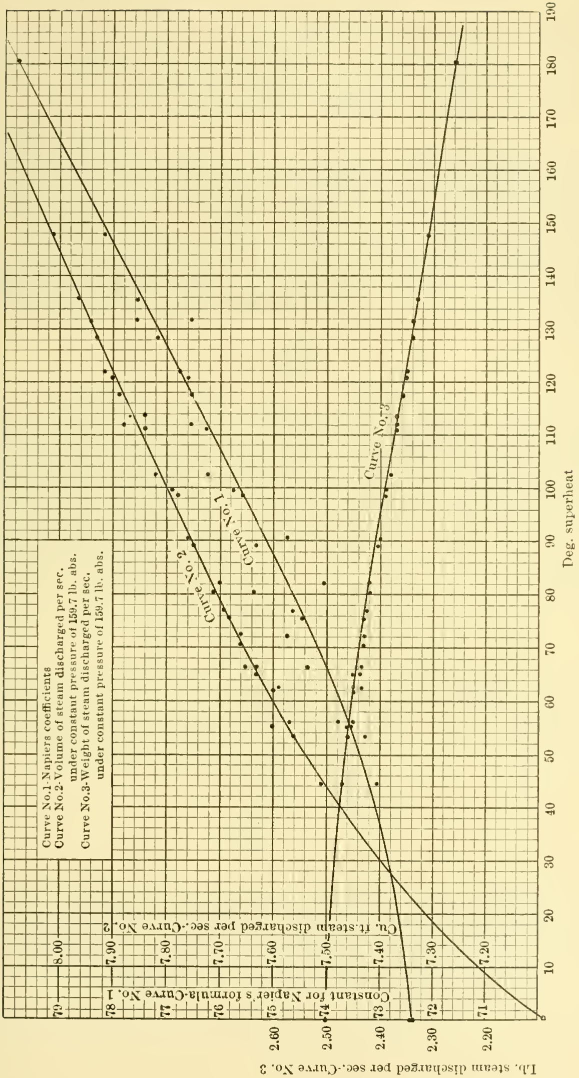

Fig. 1 Results of Tests

where C_1 = Napier's coefficient
p = the various test pressures in lb. per sq. in. abs.
W = the weight of steam flowing per sec. in lb.
a = the area of the orifice in sq. in.

9 In curve No. 2, the cu. ft. of steam discharged per sec. is shown for different amounts of superheat, the results being reduced to the basis of the average pressure which existed in the tests in order to make the volume discharged depend on the temperature only.

10 Writing instead of p, p_1 (159.7) an arbitrary constant pressure approximating the mean pressure of the various tests, and multiplying by V_1, the specific volume of the steam at the various superheats, we have

$$W_1 V_1 = \frac{p_1 a V_1}{C_1} \qquad \text{[2]}$$

where $W_1 V_1$ represents the volume of steam in cu. ft. per sec. which flows through the orifice for the various tests, on the assumption that the pressure was constant for all the tests. These values are plotted and form the bases of curve No. 2.

11 To solve [2] we employ the usual equation for specific volume of superheated steam, which, on substituting certain known values, becomes

$$V_1 = \frac{93.011\ T - 1097P^{0.228}}{P} \qquad \text{[3]}$$

where P = 23,040 lb. sq. in. abs. pressure, the approximate average for the tests and T = 824.1, the corresponding absolute temperature. A subsidiary formula used in arriving at the formula for V_1 is

$$\frac{k-1}{k} = \frac{(C_p - h)\ p}{T \frac{dp}{dt} C_p} \qquad \text{[4]}$$

In this formula C_p is taken at 0.525, this being the mean value most nearly approximating the temperature-pressure conditions of the various tests. The value of h employed is that given in Professor Heck's paper on the Thermal Properties of Superheated Steam.[1] The value $\frac{dp}{dt}$ employed corresponds to the pressure and temperature as given above and equals 1.9943. The pressure is of course a linear factor in Napier's coefficient with saturated steam, and even though it is not so with superheated steam, the results are interesting as indicating how far from constant the coefficient is for superheated steam for the given pressure.

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[1] Trans. Am. Soc. M. E., vol. 30, p. 292.

12 Dividing the value given in curve No. 2 by the specific volume V_1 corresponding to the observed temperature, and the constant pressure p_1 (159.7), we have the weight of W_1 discharged, assuming that the initial pressure remains constant and equal to p_1. These values are plotted and form the bases of curve No. 3, the weight of W_1 being determined by means of the equation

$$W_1 = \frac{p_1 a}{C_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad [5]$$

13 No quantitative results can be obtained from these data to show the effect of superheat on flow of steam in piping, but in general they seem to indicate the necessity of investigation and probable revision of the assumption frequently made that substantially smaller pipe sizes can be used for the transfer of a given amount of energy with a given pressure drop.

COMBUSTION AND BOILER EFFICIENCY

THE IMPORTANCE OF CARBON DIOXIDE AS AN INDEX TO COMBUSTION AND, IN CONNECTION WITH FLUE-GAS TEMPERATURE, TO BOILER EFFICIENCY

By Edw. A. Uehling, Passaic, N. J.

Member of the Society

It is now fully recognized by all progressive and observing engineers and managers of power houses that there is more room for economy in the boiler house than in any other part of the plant. It is therefore not due so much to lack of recognition of the fact that there is still from 5% to 25% of the available energy of the coal needlessly wasted that this waste continues to an appalling degree, as to the inherent difficulty in regulating combustion so that the loss may be reduced to a minimum.

2 A steam engine correctly designed, properly constructed, accurately adjusted and adapted to the work to be performed will give maximum economy. The attendant can do little or nothing either to increase or to decrease its efficiency. This is true also, and perhaps even to a greater degree, of the steam turbine and the dynamo. Certain definitely fixed and automatic adjustments having been found to give maximum economy, the efficiency will continue so long as these adjustments are maintained. An occasional economy test is all that is required to maintain maximum efficiency.

3 The efficiency of the steam generator depends on far more complex conditions, many of which are not only beyond control but are continually changing. Some of them are: First, *atmospheric conditions*; i.e., the barometric pressure, humidity of the atmosphere, direction and velocity of the wind, all of which affect combustion. Second, *the quality of the fuel*, which at best is never quite uniform, even when similar in kind, and often varies greatly in its con-

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tent of moisture, fixed carbon, volatile combustible matter, oxygen, ash, etc.; also its physical condition, unless specially prepared, may and often does vary from large lumps to fine powder. Third, *the condition of the boiler* as to setting, dirty heating surface, air infiltration, draft, etc. The grates become choked with slate and clinker, obstructing the air passage and causing irregular flow, resulting in a deficiency in one place and an excess in another. Every one of these variables affects the efficiency of the boiler furnace. Fourth, *the required output,* which varies in some plants between very wide limits, not infrequently from 50% overload to 50% below normal capacity in short intervals of time.

4 From the foregoing it becomes quite evident that steam-boiler economy is a complex problem, and no matter how well a boiler may be designed and how perfectly constructed, it cannot be permanently adjusted to operate with maximum efficiency under the varying conditions which obtain, even under the most favorable circumstances. Permanent adjustments of a steam boiler cannot be made, as in a steam engine, to obtain maximum efficiency.

5 The heat energy carried off by the flue gas in general boiler-room practice is rarely as low as 15% and not infrequently reaches 40% of the calorific value of the fuel burned under the boiler.

6 This loss is made up of two distinct factors, the sensible heat of the flue gas and the potential heat of the combustible constitutents it contains. The former varies directly as the stack temperature and inversely as the percentage of CO_2. The latter is independent of the stack temperature, but for any given percentage of combustible constitutents in the flue gas the loss also varies inversely as the percentage of CO_2. The only heat loss that is independent of the percentage of CO_2 in the flue gas is that due to the moisture contained in the fuel, but it is dependent on the stack temperature. The percentage of CO_2 and the stack temperature are, therefore, the two controlling factors.

7 For any given boiler and setting driven at a given rate the temperature of the flue gas depends on the condition of the heating surface and on the amount of air infiltration. When the heating surface becomes dirty, either inside or outside, or both, the stack temperature will be correspondingly higher, other conditions being the same. Air infiltration lowers the stack temperature in proportion to its ratio to the actual products of combustion. We have, therefore, two conflicting conditions that influence the stack temperature. Because of dirty heating surface, it should be above normal, but air

infiltration may actually bring it below normal, so that the stack temperature alone cannot be depended upon as an index to either economical or wasteful operation, especially since it gives no clue to the efficiency of the furnace.

8 When excessive air infiltration takes place, it becomes manifest at once by an abnormally low percentage of CO_2, so that a knowledge of the latter is necessary to understand the true significance of the former. Hence, it is evident that to produce maximum economy, or even good average results, some means should be provided to indicate to the attendant continuously what his fires are doing.

9 Provided the boiler is properly designed and set and is otherwise in proper condition, i.e., clean inside and out, its economy depends entirely on the regulation of the furnace. This again depends upon the regularity of fuel and air supply in the correct proportion and through the proper channels. Since the composition of the products of combustion gives immediate evidence of the furnace operation, it follows that in the analysis of the flue gases lies the key to the attainment of maximum efficiency, and the most progressive engineers and managers of power plants have employed gas analysis in a more or less thorough manner as a means for obtaining increased boiler-house economy.

10 Since the excess of oxygen is necessary for complete combustion, it is held by some combustion experts that O is a better index to the efficiency of combustion and boiler economy than CO_2.

11 A study of the classified tables of analyses given in Appendix No. 1, and more especially a study of the diagrams (Figs. 1 to 4) plotted from these analyses, may lead to the conclusion that the percentage of O might answer as well as the percentage of CO_2, but hardly better. When we consider that CO_2 is very much more readily determined than O, and that there are a number of practicable instruments on the market that will autographically record the percentage of CO_2 in the flue gas at short intervals, one of which will make a continuous record and at the same time indicate the percentage of CO_2 at the boiler front, there can be little room for doubt as to which of the constituents is the better adapted to serve as the index of economical combustion.

12 It may be questioned whether a knowledge of the percentage of CO_2 is sufficient for economical firing. Is it not necessary to know the percentage of oxygen (O), carbon monoxide (CO), hydrogen (H) and hydrocarbons (C_xH_y) as well?

13 For scientific tests and investigations, complete analyses of the products of combustion should always be made, and if in addition a heat balance is to be made, it is necessary to determine the weight of the coal, the volume or weight of the water, the qualtiy of the steam as to entrained moisture and superheat, and the weight of ash and the unconsumed carbon it contains. It is evident that such tests can only be carried on by an expert with the necessary scientific apparatus and the help of competent assistants. They are, therefore, not available for every-day practice. Occasional tests are undoubtedly of great value, especially for the purpose of determining the most economical percentage of CO_2 for the kind of fuel used and the conditions prevailing, but what is needed is a continuously available index. For such index the choice can lie only between CO_2 and O and, for reasons already given, CO_2 is much to be preferred.

14 The tables of analyses and the graphic illlustrations show conclusively that under normal conditions of combustion there is a very definite relation between the percentage of CO_2 and O contained in the flue gas. The percentage of O falls almost exactly in the same ratio as CO_2 goes up and vice versa. The analyses also show conclusively that there is no relation between either O or CO_2 and CO. High O and low CO_2 is no guarantee that CO may not be present, nor does it follow that high CO_2 and low O means incomplete combustion. All that we can discern with certainty is that there is a tendency toward higher CO as the percentage of CO_2 goes up. This tendency increases very moderately at the lower range of CO_2 but more and more rapidly as the maximum percentage of CO_2 is reached. Since the ratio of carbon burned to CO to that burned to CO_2 equals $\frac{P_c}{P + P_c}$ (see Par. 51), it follows that the loss (L_c) due to carbon monoxide for the same percentage of CO varies inversely as the percentage of CO_2, e.g., 1% of CO in flue gas containing 5% of CO_2 causes as great a loss as 3% CO associated with 15% of CO_2. The same holds true of the loss due to all the combustion products with the exception of the moisture contained in the fuel. The general conclusion that the chimney heat loss varies inversely as the percentage of the CO_2 in flue gas seems, therefore, warranted. Modifying influences are considered in Pars. 22 to 26.

15 The tables in Appendix No. 1 constitute 1130 flue-gas analyses from various sources, representing many kinds of fuel and furnace conditions. These analyses were classified in Tables 1, 3, 5, 7 and 9 with reference to the percentage of CO_2 and in Tables 2, 4, 6, 8

and 10 with reference to the percentage of O. For the benefit of those who kindly furnished a large number of these analyses, they were further classified according to source and some of these again with reference to totals obtained by adding together the three oxygen components, viz., CO_2, O and CO.

16 The right-hand column of each table gives the total of the components determined and it will be noticed that these totals vary considerably. In the Government analyses (Tables 1 and 2) they vary from 16.7% to 20.8%, i.e., fully 4.1% of the total gas or 20% from one another. There is, however, only one instance below 17% and only four below 18%, 20 between 18% and 19%, 287 between 19% and 20%, and 277 between 20% and 20.8%, which is the highest total found.

17 The sum of the percentages of CO_2, O and CO contained in flue gas varies with the excess of air, the degree of completeness of combustion, the composition of the fuel and the temperature at which the gas is analyzed. When combustion is complete and the fuel consists of carbon only, the sum of CO_2 and O cannot exceed the percentage of oxygen in the air, viz: 21% (see Par. 47). It will always be less than this, because the gas is saturated with moisture, which in general gas analyses is reckoned with the nitrogen. This introduces a possible difference of 1.3% due to the differences in the moisture content of the gas between 62 deg. and 92 deg., a range of 30 deg.

18 *Incomplete Combustion.* When carbon is burned to CO every molecule of O_2 combines with two atoms of carbon and forms two molecules of CO. The gas may, therefore, contain 34.7% of CO as a maximum. Therefore, if combustion is incomplete and CO is present, the sum of $CO_2 + O_2 + CO$ in dry gas may be greater than 21% by an amount equal to $\frac{34.7-21}{34.7} \times CO = 0.4\ CO$, so that in this case the sum of the oxygen components in saturated gas would be $21 + 0.4\ CO - \frac{H_2O \times 21}{100}$. Since the percentage of CO in normal flue gas reaches 1% only in exceptional cases and the reduction due to moisture is not likely to be less than 1%, flue-gas analyses in which the sum of the oxygen components exceeds 21% must be looked on with suspicion.

19 In burning fuel containing any considerable quantity of hydrogen the sum of CO_2+O_2+CO will always be less than 21% in

normal flue gas, because all the oxygen which combines with the H_2 forms water vapor, which is condensed, while the nitrogen remains as a diluent. Carbon and hydrogen require respectively 152 and 457 cu. ft. of air for complete combustion (see Par. 47 and 55). The products of combustion are composed of 31.92 cu. ft. of CO_2 and 120.08 cu. ft. of nitrogen for carbon and 361 cu. ft. of nitrogen for hydrogen. When burning fuel containing a high ratio of available hydrogen to carbon, Illinois bituminous coal for example, in which $\frac{H_a}{C} = 0.06$, assuming complete combustion with the theoretically required volume of air, then $\frac{152 \times 21}{152+(361 \times 0.06)} = 18.4\%$ is the maximum CO_2 obtainable from this coal. If the above coal is burned with 50% excess of air, again assuming complete combustion, the flue gas would be composed of $\frac{152 \times 21}{228 + 32.5} = 12.25\%$ CO_2 and $\frac{86.8 \times 21}{228 + 32.5} = 7\%$ O, or a total of 19.25%. Now if we assume the gas to contain 0.5% CO, the sum of $CO_2+O_2+CO = 12.25 +7+0.4 \times 0.5 = 19.45\%$. If the gas were analyzed at a temperature of 92 deg. the result would be 9.6% less than the above, due to moisture in the gas. The analytical result would therefore be 17.58%.

20 This is an extreme case, but it shows that large variations may legitimately occur in the sum of the oxygen components contained in combustion products. It also shows that the temperature at which gas analyses are made should be taken into consideration. It brings out the further fact that the maximum percentage of CO_2 that may be contained in flue gas decreases as the ratio of carbon to hydrogen in the coal increases, from which it becomes evident that the most economical percentage of CO_2 must vary with the kind of fuel. It will be several per cent higher with anthracite than with bituminous coal, and varies in the latter with the ratio of carbon to available hydrogen.

21 The highest practicable furnace efficiency obtains when the greatest possible part of the potential energy contained in the coal is converted into sensible heat by combustion. The highest boiler efficiency results when a minimum of this heat is carried off by the flue gas. The former is realized when combustion is complete, the

latter when the weight and temperature of the flue gas are a minimum. Since the weight of flue gas decreases as the percentage of CO_2 increases, high boiler efficiency requires high CO_2.

22 On the other hand, when the furnace is run so as to produce a maximum percentage of CO_2 there is danger of reducing its efficiency because of incomplete combustion due to a minimum of free oxygen. It would seem, therefore, that the highest combined efficiency of boiler and furnace would be obtained when the gain due to reduced weight of flue gas, i.e., due to an increased percentage of CO_2 is balanced by the loss due to incomplete combustion.

23 The most economical percentage of CO_2 varies theoretically with the ratio of available hydrogen to carbon $\left(\frac{H_a}{C}\right)$, but in practice it is influenced by many modifying conditions. In every case, however, there is a percentage of CO_2 which gives best results. Its value as an index, therefore, is not dependent on the kind of fuel used or the local conditions existing.

24 Next to careless or unskillful firing, air infiltration causes the greatest loss in the flue gas. Unless especially provided against, it is rarely less than 15 to 20% of the volume of the flue gas and not infrequently reaches 50% and over when cracks in the settings are allowed to exist and warped and badly fitting cleaning doors are tolerated. Professor Breckenridge, in his discussion of the boiler tests carried on by the Government under his direction at St. Louis, estimates the air infiltration at from 25 to 30%, and it would be presumptuous to assume that the boilers used for these tests were not in at least as good condition as those in the average power plant.

25 Comparing Tables 1 and 2 with Tables 5 and 6 it will be noticed that the percentage of CO_2 is much lower in the former than in the latter set of analyses and, what is even more striking, that CO occurs with greater frequency and in larger amount in the Government tests than in those represented in Tables 5 and 6. It would seem proper to infer that this is due, largely at least, to much greater air infiltration in the former case than in the latter and that at least 20% should be added to the CO_2 and CO, and subtracted from the O in order to represent correctly the composition of the combustion products formed in the furnace. From Tables 5 and 6 it is apparent that a high percentage of CO_2 is possible without undue loss of combustible in the flue gas.

26 Tables 7 and 8 are peculiar in that the sum of the oxygen components is below 19%. Compared with Tables 5 and 6 oxygen

is low, and the CO is rarely absent and comparatively very high. Unfortunately there are no data upon which to base an explanation. It is probable, however, the analyses in Tables 7 and 8 were made at a higher temperature than those in Tables 1, 2, 3 and 4. It is also possible that the oxygen may not have been fully absorbed, but this is mere conjecture. The high percentage of CO, even in connection with a comparatively moderate percentage of CO_2, points to injudicious firing. There are good reasons, however, to suspect that there is something wrong with these analyses and part of those in Tables 9 and 10. These reasons are given in Par. 32.

27 Tables 3 and 4 show a set of analyses which were obtained from tests of a locomotive under widely varying conditions of forced draft, which ranged from 0.59 in. to 11.8 in. of water, the corresponding rates of driving varying from 19.2 lb. to 114.6 lb. of coal burned per sq. ft. of grate surface per hr. The analyses are unique, because of the facts just mentioned and because conditions absolutely preclude air infiltration. The oxygen components in this set of analyses vary less than 1%, which is as it should be, the coal used being similar in kinds in all the tests. The comparatively low and uniform percentage of CO is remarkable considering the extreme variation in the rate of driving.

28 The lowest percentage of CO in these tests occurs with an excess of 6.92% O and the highest 0.3 % CO with an excess of 6.74% O. The average excess of O in the upper seven analyses is 7.5% in the lower seven analyses it is 6.1%, a difference of 1.4%, yet the average percentage of CO is almostly the same, viz., 0.17%. The respective average percentages of CO_2 are 11.33 and 12.91, a difference of 1.58%. This corroborates the statement previously made that within moderate limits the percentage of CO does not vary either with the percentage of O or with the percentage of CO_2 contained in the flue gas. So far as these analyses indicate, it is also independent of the rate of driving.

29 Tables 5 and 6 are peculiar in that they contain no analysis in which the sum of the oxygen component is less than 19%. This set of analyses is remarkable because CO was found in only ten of the 167 six-hour samples represented, and only two of these contained as high as 0.4% of this constituent, accompanied respectively by 9.9% of CO_2 and 8.9% of O, and 12% of CO_2 and 6.6% of O. It is not until the CO_2 exceeds 10% and the O falls below 6% that CO appears with some frequency. Taking the last seven analyses of Table 6 we find an average of 13.4% CO_2 and 0.1% CO.

30 We have shown in Par. 19 that when burning coal in which $\frac{H_a}{C} = 0.06$ with 50% excess of air the flue gas should contain 12.25% CO_2 and 7% O. It would, therefore, seem reasonable to conclude that when burning coal in which the ratio $\frac{H_a}{C}$ does not exceed 0.05, if the CO exceeds 0.2% or at most 0.3% in flue gas containing 12% to 14% of CO_2 and 7% to 5% of O there is something wrong with the method of firing, the furnace, the construction, the setting or all of them.

31 In Pars. 17 to 20 an attempt is made to show why the sum of the oxygen components contained in flue gas does vary and to what extent it may vary legitimately. It was shown that a considerable variation may be due to a variation in the temperature at which the gas is analyzed, that the presence of CO augments the sum of the oxygen components by 0.4 of its value, and that the presence of H_2 in the fuel reduces this sum very materially. It follows, then, that for similar fuel the higher percentage of CO should coincide with the higher sum of the oxygen components.

32 In the tables the analyses in which the sum of the oxygen components is less than 19% are marked with a star, and all those in which the CO exceeds 0.3% are marked with a cross. Examining Table 1, we find that 69 out of the 609 analyses show CO above 0.3%, and in only five of these is the sum of the oxygen components less than 19%. In Table 9 we find that in a total of 126 samples, 36 contain over 0.3% of CO, every one of which occurs with oxygen components summing up to less than 19%. Table 7 shows the same discrepancy. Out of the 224 analyses there tabulated, 67 show CO above 0.4%, for all of which the oxygen components are below the average. So far as we know, the coal burned did not vary greatly, certainly not nearly so much as in the Government tests. We feel justified, therefore, in doubting the correctness of the analyses given in Tables 7 and 8 and no weight should be attached to them in drawing conclusions. We think it none the less proper to include them in this paper with our reason for doubting their correctness.

DIAGRAMATIC REPRESENTATION OF ANALYSES

33 The averages varying by 0.1% of Tables 1, 2, 3 and 4 are plotted in Fig. 1, those of Tables 5 and 6 in Fig. 2, and those of

Tables 7 and 8 ,and 9 and 10 respectively in Figs. 3 and 4. The straight lines represent the theoretical amounts of CO_2 and O which the combustion products would contain if pure carbon were burned with pure air. The analyses were plotted with regard to the percentage of CO_2 and O respectively. The CO_2 was placed in its proper position on the theoretical CO_2 line for the percentages of CO_2 and then the accompanying percentages of O and CO were plotted on the same ordinate in the position called for by their value. In the same manner the O was placed on the theoretical oxygen line and the CO_2 and CO were plotted according to their values on the same ordinate. To show the values of CO more clearly, they are multiplied by five.

34 Fig. 1 shows that the percentage of O diminishes as the CO_2 increases, and vice versa, the percentage of CO_2 increases as the O becomes less. It will be noted that both the O and CO_2 lines converge toward the theoretical line as the CO_2 diminishes, which is as it should be if the analyses are correct, because when the CO_2 is zero, the percent of O must be that of the air, viz., 21%. The amount of divergence from the theoretical line towards zero O depends on the value of $\frac{H_a}{C}$ in the fuel.

35 Considering the great variety of fuels represented by the Government analyses it is remarkable with what uniformity the CO_2 and O vary in accordance with what should be expected from theoretical considerations. This becomes even more remarkable when we observe how harmoniously the analyses of Tables 3 and 4 (represented by the somewhat heavier lines) fit in with those of Tables 1 and 2, especially when we consider that the latter were derived from entirely different test conditions. From this we may be justified in concluding that the relation of CO_2 to O shown in Fig. 1 holds true for all ordinary conditions of simple combustion. It therefore follows that if we know the percentage of CO_2 contained in the products of combustion we may infer from it with a practical degree of approximation the accompanying percentage of O, and vice versa.

36 That no such reliable relation exists between the CO and either of the former has already been stated. That this should be so becomes quite evident when we consider that the relation between CO_2 and O depends on a natural law, whereas the percentage of CO in a large degree depends on caprice. In Table 2 we find 0.5% CO with 13.6% of O and in Table 6 we find analyses which show complete combustion with less than 6% of O. It is evident, therefore,

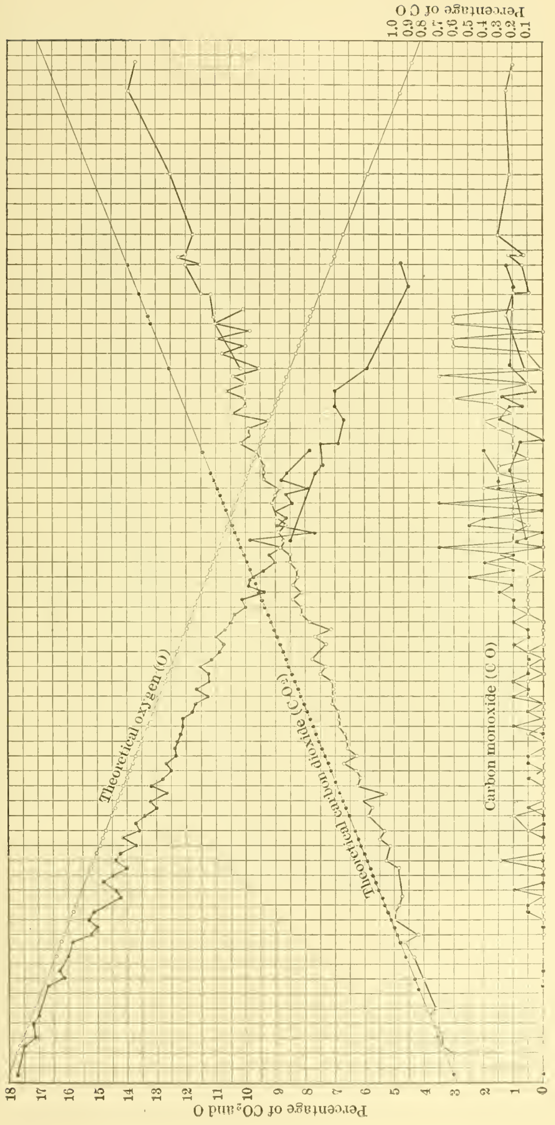

FIG. 1 DIAGRAMATIC REPRESENTATION OF ANALYSES GIVEN IN TABLES 1, 2, 3 AND 4

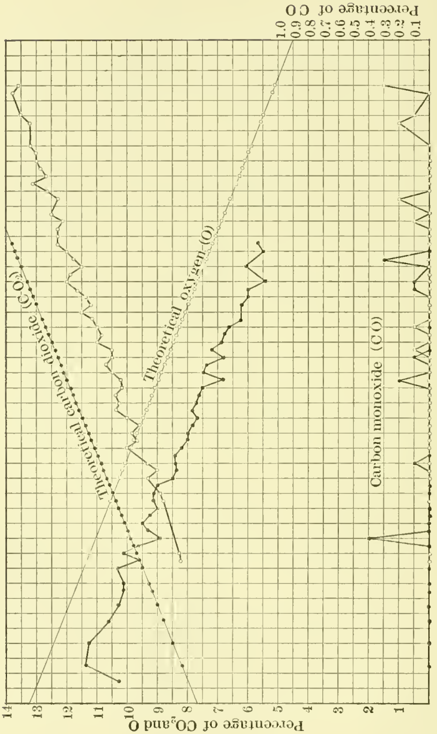

FIG. 2 DIAGRAMATIC REPRESENTATION OF ANALYSES GIVEN IN TABLES 5 AND 6

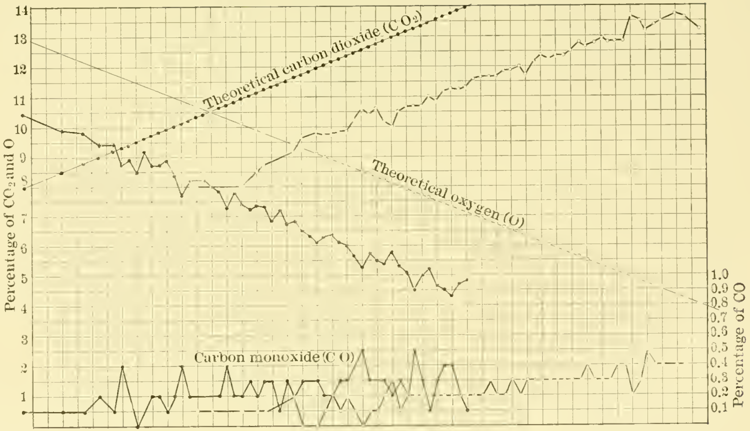

FIG. 3 DIAGRAMATIC REPRESENTATION OF ANALYSES GIVEN IN TABLES 7 AND 8

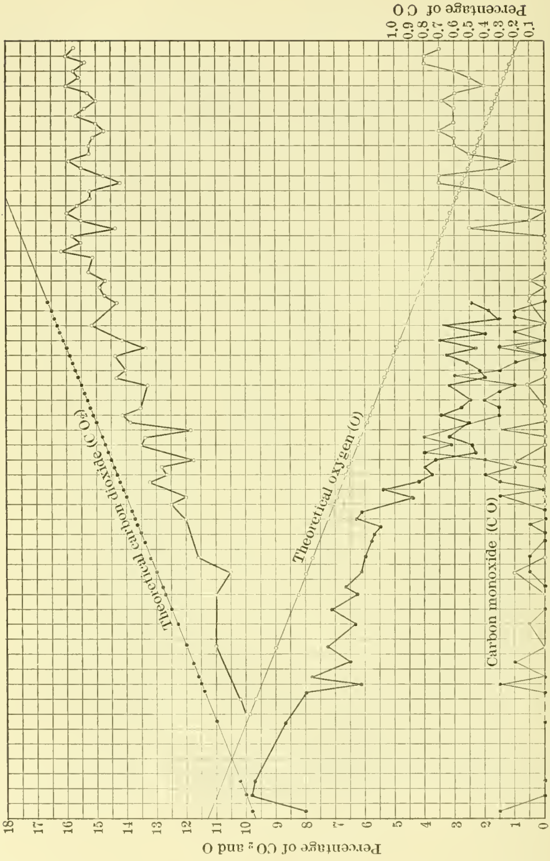

FIG. 4 DIAGRAMATIC REPRESENTATION OF ANALYSES GIVEN IN TABLES 9 AND 10

that 6% of O is sufficient when the conditions are right and that a large percentage of O will not insure complete combustion when the conditions are bad.

37 The CO line in Fig. 1 illustrates the irregularity of this component. It was stated at the outset that the tendency toward a higher percentage of CO in flue gas becomes increasingly greater as the percentage of CO_2 goes up; but the diagram shows a maximum of over 0.4% of CO with CO_2 between 10% and 11%, whereas with CO_2 between 11% and 14% the CO does not average above 0.2%. This apparent anomaly is explained by the fact that Government analyses include from 20 to 30% of infiltrated air and that the real combustion products contained about 25% more CO_2 and 25% less O than the analyses show. In reality, therefore, the high CO readings occurred with CO_2 from 12.5 to 13.75%. This would place the high CO in its proper relation to CO_2, but the contrast as compared with the CO found in the flue gas of the locomotive test still remains and is evidence of uneconomical firing.

38 Passing to Fig. 2 we notice the same characteristics as in Fig. 1, viz., the O line follows a trend which should meet the theoretical O line at 21% when CO_2 reaches zero, and the CO_2 follows a trend which would meet the zero point of the theoretical CO_2 line when O reaches 21%. The CO is irregular and has a moderate tendency towards higher values as the CO_2 reaches the higher values. With the exception of the few analyses previously discussed, this diagram shows very good combustion.

39 Fig. 3 corroborates what has already been said about the analyses from which it was plotted. The CO line is irregular and high, and only slightly higher with CO_2 above 11% than below. Both the CO_2 and the O line show that the analyses are deficient in the O components, nor does the trend of the O line converge toward the theoretical line as it should. The correctness of the analyses in Tables 7 and 8 must, therefore, stand questioned, and other than showing this fact, little value can be attached to the diagrams in Fig. 3.

40 The suspicion as to the correctness of the analyses in Tables 9 and 10 is strengthened to an even greater extent by study of Fig. 4. The analyses appear to be particularly faulty with the higher CO_2 and the correspondingly lower O content. The high and erratic CO line shows that the firing must have been irregular and bad. But reliable conclusions cannot be drawn from this diagram except that at least a large number of the analyses cannot be considered reliable.

CALCULATION OF HEAT CARRIED OFF BY THE FLUE GAS

41 In Appendix No. 2 an attempt has been made to formulate simple equations by which the heat and heat energy carried off by the flue gas can readily be calculated for all kinds of fuel, provided we have a correct analysis of the fuel burned and the flue gas produced.

CONCLUSIONS

42 We must conclude from these calculations that the percentage of CO_2 and the stack temperature are the two controlling factors in the production of furnace and boiler efficiency. In view of the fact that both of these components are so easily determined and that apparatus is in existence which will continuously indicate and record them, it is lamentable that more general use is not made of these indexes.

43 There is today no valid reason why scientific methods should not prevail in securing fuel, as well as in consuming it, especially for power purposes, nor is there any reason why consumers of large quantities of coal should be ignorant of its ultimate, as well as its proximate composition.

44 It is not generally feasible, nor is it at all necessary, in order to obtain the most economical results, that calculations be based on the ultimate analysis of the coal, but a full analysis of the flue gas should form part of the daily routine. Inasmuch, however, as the most economical percentage of CO_2 varies considerably with the kind of fuel used, and also to some extent on the method of firing, hand or mechanical, the kind of stoker and rate of driving, it becomes very desirable, if not absolutely necessary, to make a series of tests in which all the essential elements are determined.

45 Having established the most economical value of CO_2, this component of the flue gas will serve as a correct guide to the fireman. An automatic record, preferably a continuous one, for the engineer is of the greatest value. If, in addition, the stack temperature is indicated for the fireman and recorded for the engineer in charge there should be little difficulty in getting maximum efficiency.

APPENDIX NO. 1

GAS ANALYSES FROM VARIOUS SOURCES

U. S. Government Tests[1]

TABLE 1

Arranged According to CO_2

	CO_2	O	CO	Total
	2.0	18.4	0	20.4
	3.0	17.7	0	20.7
	3.4	17.5	0	20.9
	3.4	17.6	0	21.0
Aver.	3.4	17.5	0	
	3.5	17.1	0	20.6
	3.7	17.3	0	21.0
	3.7	17.1	0	20.8
Aver.	3.7	17.2	0	
	3.8	16.7	0	20.5
	3.8	17.2	0	21.0
Aver.	3.8	17.0	0	
	4.0	16.1	0	20.1
	4.2	16.7	0	20.9
	4.3	16.1	0	20.4
	4.4	16.1	0	20.5
	4.4	16.4	0	20.8
Aver.	4.4	16.3	0	
	4.6	16.2	0	20.8
	4.6	15.7	0	20.3
Aver.	4.6	16.0	0	
	4.8	16.2	0	21.0
	4.8	15.8	0	20.6
	4.8	15.6	0	20.4
Aver.	4.8	15.9	0	

TABLE 2

Arranged According to O

	O	CO_2	CO	Total
	18.4	2.0	0	20.4
	17.7	3.0	0	20.7
	17.6	3.4	0	21.0
	17.5	3.4	0	20.9
	17.3	3.7	0	21.0
	17.2	3.8	0	21.0
	17.1	3.5	0	20.6
	17.1	3.7	0	20.8
Aver.	17.1	3.6	0	
	16.7	4.2	0	20.9
	16.7	3.8	0	20.5
Aver.	16.7	4.0	0	
	16.4	4.4	0	20.8
	16.2	4.6	0	20.8
	16.1	4.0	0	20.1
	16.1	4.3	0	20.4
	16.1	4.4	0	20.5
Aver.	16.1	4.2	0	
	15.9	5.0	0	20.9
	15.8	4.8	0	20.6
	15.8	5.2	0	21.0
Aver.	15.8	5.0	0	

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[1] Coal Testing Station, Louisiana Purchase Exposition, U. S. Geological Survey Report, Part 2, Boiler Tests.

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	4.9	15.2	0	20.1
	5.0	14.7	0.1	19.8
	5.0	15.9	0	20.9
	5.0	15.0	0	20.0
	5.0	14.4	0	19.4
Aver.	5.0	15.0	0	
	5.1	15.7	0	20.8
	5.1	14.9	0	20.0
Aver.	5.1	15.3	0	
	5.2	15.8	0	21.0
	5.2	14.7	0.2	20.1
	5.2	14.8	0	20.0
Aver.	5.2	15.1	0.1	
	5.3	15.1	0.3	20.7
	5.3	14.8	0.1	20.2
	5.3	14.9	0	20.2
	5.3	13.9	0	19.2
	5.3	14.7	0	20.0
Aver.	5.3	14.7	0.1	
	5.4	14.2	0	19.6
	5.5	14.4	0.2	20.1
	5.6	14.8	0	20.4
	5.6	15.0	0	20.6
	5.6	14.5	0	20.1
Aver.	5.6	14.8	0	
	5.7	14.4	0	20.1
	5.7	14.5	0	20.2
Aver.	5.7	14.5	0	
	5.8	13.4	0.3	19.5
	5.8	12.7	0	18.5
	5.8	14.7	0	20.5
	5.8	14.8	0	20.6
	5.8	14.3	0	20.1
Aver.	5.8	14.0	0	
	5.9	14.5	0	20.4
	5.9	14.1	0	20.0
	5.9	14.7	0	20.6
	5.9	14.0	0	19.9
	5.9	14.5	0.2	20.6
Aver.	5.9	14.4	0	20.3

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	15.7	5.1	0	20.8
	15.7	4.6	0	20.3
Aver.	15.7	4.9	0	
	15.6	4.8	0	20.4
	15.2	4.9	0	20.1
	15.1	5.3	0.3	20.7
	15.0	5.0	0	20.0
	15.0	5.6	0	20.6
Aver.	15.0	5.3	0	
	14.9	5.3	0	20.2
	14.9	5.1	0	20.0
Aver.	14.9	5.2	0	
	14.8	5.2	0	20.0
	14.8	5.3	0.1	20.2
	14.8	5.8	0	20.6
	14.8	5.6	0	20.4
Aver.	14.8	5.5	0	
	14.7	5.9	0	20.6
	14.7	5.8	0	20.5
	14.7	5.3	0	20.0
	14.7	5.2	0.2	20.1
	14.7	5.0	0.1	19.8
Aver.	14.7	5.4	0.1	
	14.5	6.2	0.2	20.9
	14.5	6.2	0	20.7
	14.5	6.0	0	20.5
	14.5	5.9	0.2	20.6
	14.5	5.9	0	20.4
	14.5	5.7	0	20.2
	14.5	5.6	0	20.1
Aver.	14.5	5.9	0.1	
	14.4	5.0	0	19.4
	14.4	6.2	0	20.6
	14.4	6.0	0	20.4
	14.4	6.0	0	20.4
	14.4	6.0	0	20.4
	14.4	6.0	0	20.4
	14.4	5.7	0	20.1
	14.4	5.5	0.2	20.1
Aver.	14.4	5.8	0	

U. S. Government Tests

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	6.0	14.4	0	20.4
	6.0	14.4	0	20.4
	6.0	14.5	0	20.5
	6.0	13.6	0	19.6
	6.0	14.0	0	20.0
	6.0	14.4	0	20.4
	6.0	14.4	0	20.4
Aver..........	6.0	14.2	0	
	6.1	13.7	0	19.8
	6.1	13.6	0	19.7
	6.1	13.7	0	19.8
Aver..........	6.1	13.7	0	
	6.2	14.4	0	20.6
	6.2	14.5	0	20.7
	6.2	14.1	0	20.3
	6.2	14.5	0.2	20.9
	6.2	13.7	0	19.9
	6.2	13.2	0	19.4
Aver..........	6.2	14.1	0	
	6.3	13.1	0	19.4
	†6.3	12.7	0.4	19.4
	6.3	14.3	0	20.6
	6.3	14.3	0	20.6
	6.3	13.7	0	20.0
Aver.........	6.3	13.6	0.1	
	6.4	13.4	0	19.8
	6.4	13.8	0	20.2
	†6.4	13.6	0.5	20.5
	6.4	13.7	0	20.1
	6.4	14.0	0	20.4
	6.4	13.4	0	19.8
	6.4	13.6	0	20.0
	6.4	13.6	0	20.0
	6.4	14.0	0	20.4
Aver.........	6.4	13.7	0	
	6.5	14.2	0	20.7
	6.5	12.9	0.3	19.7
	6.5	13.0	0	19.5
	6.5	13.1	0.1	19 7
	6 5	13.5	0	20.0
	6.5	13.8	0	20.3
Aver.........	6.5	13.4	0	
	6.6	13.3	0.3	20.2
	6.6	13 5	0	20.1
	6.6	13 6	0	20.2

Continued on next page

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO	CO	Total
	14.3	5.8	0	20.1
	14.3	6.3	0	20.6
	14.3	6.3	0	20.6
Aver..........	14.3	6.1	0	
	14.2	5.4	0	19.6
	14.1	5.9	0	20.0
	14.1	6.2	0	20 3
	14.1	6.7	0	20.8
Aver..........	14.1	6.3	0	
	14 0	6.4	0	20.4
	14.0	6.4	0	20.4
	14.0	6.0	0	20.0
	14.0	5.9	0	19.9
Aver..........	14.0	6.2	0	
	13 9	6.7	0	20.6
	13.9	6.9	0.1	20.9
	13.9	5.3	0	19.2
Aver..........	13 9	6.3	0	
	13.8	7.2	0	21.0
	13.8	6.8	0	20.6
	13.8	6.5	0	20.3
	13.8	6.4	0	20.2
Aver..........	13.8	6.7	0	
	13.7	6.1	0	19.8
	13.7	6.1	0	19.8
	13.7	6.2	0	19.9
	13.7	6.3	0	20.0
	13.7	6.7	0	20.4
	13.7	6.4	0	20.1
Aver..........	13.7	6.3	0	
	13.6	7.4	0	21.0
	13.6	6.8	0	20.4
	13.6	6.8	0	20.4
	13.6	6.7	0	20.3
	13.6	6.6	0.5	20.5
	13.6	6.6	0	20.2
	13.6	6.4	0	20.0
	13.6	6.4	0	20.0
	13.6	7.1	0	20.7
	13.6	6.1	0	19.7
	13.6	6.0	0	19.6
Aver..........	13.6	6.6	0	
	13.5	6.6	0	20.1
	13.5	6.5	0	20.0
Aver..........	13.5	6.6	0	

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
		Continued		
	6.6	12.6	0	19.2
	6.6	13.3	0	19.9
	6.6	13.0	0.1	19.7
	6.6	12.5	0	19.1
	*6.6	12.2	0	18.8
	†6.6	12.7	0.5	19.8
	6.6	13.4	0.2	20.2
	6.6	13.6	0.3	20.5
	6.6	12.8	0	19.4
	*6.6	11.2	0	17.8
	6.6	13.0	0	19.6
	6.6	12.8	0	19.4
	6.6	13.9	0	20.5
Aver........	6.6	13.0	0.1	
	6.7	12.9	0	19.6
	6.7	13.9	0	20.6
	6.7	12.8	0	19.5
	6.7	12.8	0	19.5
	6.7	12.9	0	19.6
	*6.7	11.5	0	18.2
	6.7	13.4	0	20.1
	6.7	13.4	0	20.1
	6.7	13.7	0	20.4
	6.7	13.6	0	20.3
	6.7	14.1	0	20.8
Aver..........	6.7	13.2	0	
	6.8	13.2	0	20.0
	6.8	13.7	0	20.4
	*6.8	11.2	0	18.0
	*6.8	10.6	0	17.4
	6.8	13.2	0	20.0
	*6.8	11.1	0.1	18.0
	6.8	13.0	0	19.8
	6.8	13.8	0	20.6
	6.8	13.6	0	20.4
Aver.........	6.8	12.6	0	
	6.9	13.3	0	20.2
	6.9	12.2	0	19.1
	6.9	13.9	0.1	20.9
	6.9	13.3	0	20.2
	6.9	13.1	0	20.0
	6.9	13.3	0	20.2
	6.9	13.3	0	20.2
	6.9	13.3	0	20.2
	6.9	12.7	0	19.6
Aver..........	6.9	13.2	0	

TABLE 2—Continued

Arranged According to O

	O	CO_2	CO	Total
	13.4	6.4	0	19.8
	13.4	6.4	0	19.8
	13.4	6.7	0	20.1
	13.4	6.7	0	20.1
	13.4	7.0	0.4	20.8
	13.4	7.2	0.3	20.9
	13.4	6.6	0.2	20.2
Aver..........	13.4	6.7	0.1	
	13.3	7.1	0	20.4
	13.3	7.0	0	20.3
	13.3	6.9	0	20.2
	13.3	6.9	0	20.2
	13.3	6.9	0	20.2
	13.3	6.9	0	20.2
	13.3	6.9	0	20.2
	13.3	6.6	0	19.9
	13.3	6.6	0.3	20.2
Aver	13.3	6.9	0	
	13.2	7.4	0	20.6
	13.2	6.8	0	20.0
	13.2	6.8	0	20.0
	13.2	7.2	0	20.4
	13.2	7.2	0	20.4
	13.2	6.2	0	19.4
Aver..........	13.2	6.9	0	
	13.1	6.3	0	19.4
	13.1	7.1	0	20.2
	13.1	7.0	0	20.1
	13.1	7.0	0	20.1
	13.1	6.9	0	20.0
	13.1	6.5	0.1	19.7
	13.1	7.2	0	20.3
Aver..........	13.1	6.9	0	
	13.0	7.2	0	20.2
	13.0	7.2	0	20.2
	13.0	7.8	0	20.8
	13.0	7.8	0	20.8
	13.0	6.8	0	19.8
	13.0	6.6	0	19.6
	13.0	6.5	0	19.5
	13.0	7.0	0	20.0
	13.0	7.0	0	20.0
	13.0	7.0	0	20.0
	13.0	7.0	0.1	20.1
	13.0	6.6	0.1	19.7
	13.0	7.3	0	20.3
Aver..........	13.0	7.1	0	

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	7.0	12.6	0.1	19.7
	7.0	13.0	0	20.0
	7.0	12.4	0	19.4
	7.0	12.8	0	19.8
	7.0	13.1	0	20.1
	7.0	13.3	0	20.3
	7.0	12.2	0	19.2
	†7.0	13.4	0.4	20.8
	7.0	13.0	0	20.0
	7.0	13.0	0	20.0
	7.0	12.9	0.2	20.1
	7.0	11.9	0.1	19.0
	7.0	13.0	0.1	20.1
	7.0	13.1	0	20.1
Aver..........	7.0	12.8	0.1	
	7.1	12.2	0	19.3
	7.1	12.9	0	20.0
	7 1	12.7	0	19.8
	*7.1	9.2	0.3	16.6
	7.1	12.8	0.1	20.0
	7.1	12.4	0	19.5
	7.1	13.1	0	20.2
	7.1	13.3	0	20.4
	7.1	13.6	0	20.7
	7.1	12.7	0	19.8
[illegible]	7.1	12.5	0	
	7.2	12.2	0	19.4
	7.2	13.4	0.3	20.9
	*7.2	10.6	0	17.8
	7.2	13.2	0	20.4
	7.2	13.2	0	20.4
	7.2	11.9	0	19.1
	7.2	13.8	0	21.0
	7.2	12.7	0	19.9
	7 2	12.5	0	19.7
	7.2	12.1	0	19.3
	7.2	12.8	0	20.0
	7.2	12.8	0.6	20.6
	7.2	12 5	0.6	20.3
	7.2	12.0	0	19.2
	7.2	12.8	0	20.0
	7.2	13.0	0	20.2
	7.2	13.1	0	20.3
	7.2	12.6	0	19.8
	7.2	13.0	0	20.2
	7.2	12.5	0	19.7
Aver..........	7.2	12.6	0.1	

TABLE 2—Continued

Arranged According to O

	O	CO	CO	Total
	12.9	7.0	0.2	20.1
	12.9	6.7	0	19.6
	12.9	6.7	0	19.6
	12.9	6.5	0.3	19.7
	12.9	7.6	0	20.5
	12.9	7.6	0	20.5
	12.9	7.3	0.2	20.4
Aver..........	12.9	7.1	0.1	
	12.8	7.2	0	20.0
	12.8	7.3	0	20 1
	12.8	7.4	0	20 2
	12.8	7.6	0	20.4
	12 8	7.6	0	20.4
	12.8	6.7	0	19 5
	12.8	6.7	0	19.5
	12.8	6.6	0	19.4
	12.8	7.2	0	20.0
	12.8	7.2	0.6	20.6
	12.8	7.1	0.1	20.0
	12.8	7.0	0	19.8
	12.8	6.6	0	19.4
Aver..........	12.8	7.1	0.1	
	12.7	6.9	0	19.6
	12.7	7.1	0	19.8
	12.7	7.1	0	19.8
	12.7	7.2	0	19.9
	12.7	6.3	0.4	19.4
	12.7	5.8	0	18.5
	12.7	6.6	0.5	19 8
	12.7	7.6	0.3	20.6
	12.7	7.6	0	20.3
	12.7	7.4	0.1	20.2
	12.7	7.4	0	20 1
	12.7	7.3	0	20.0
	12.7	7.3	0	20.0
	12.7	7.3	0	20.0
Aver	12.7	7.1	0.1	
	12.6	7.2	0	19.8
	12.6	7.4	0	20.0
	12.6	7.4	0	20 0
	12.6	7.4	0	20.0
	12.6	7.5	0	20.1
	12.6	7.5	0	20.1
	12.6	7.8	0	20.4
	12.6	7.8	0	20.4

Continued on next page

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	7.3	13.0	0	20.3
	7.3	12.7	0	20.0
	7.3	12.2	0	19.5
	7.3	12.9	0.2	20.4
	7.3	11.9	0	19.2
	†7.3	12.3	0.5	20.1
	†7.3	12.5	0.5	20.3
	7.3	11.9	0	19.2
	7.3	12.2	0	19.5
	7.3	12.2	0	19.5
	7.3	12.1	0	19.4
	7.3	12.7	0	20.0
	7.3	12.7	0	20.0
	7.3	12.8	0	20.1
Aver..........	7.3	12.4	0.1	
	7.4	12.4	0	19.8
	7.4	12.4	0	19.8
	7.4	13.2	0	20.6
	7.4	12.1	0	19.5
	7.4	12.6	0	20.0
	7.4	13.6	0	21.0
	7.4	12.8	0	20.2
	*7.4	10.6	0	18.0
	7.4	12.3	0	19.7
	7.4	12.7	0	20.1
	7.4	12.0	0	19.4
	7.4	12.5	0	19.9
	7.4	12.6	0	20.0
	7.4	11.9	0	19.3
	7.4	12.6	0	20.0
	7.4	12.7	0.1	20.2
	7.4	12.0	0	19.4
	7.4	12.8	0	20.2
Aver..........	7.4	12.4	0	
	7.5	12.5	0	20.0
	7.5	12.6	0	20.1
	7.5	12.6	0	20.1
	7.5	12.5	0	20.0
	7.5	12.3	0	19.8
	7.5	11.5	0	19.0
	7.5	12.1	0	19.6
	7.5	11.7	0	19.2
	7.5	12.6	0.1	20.2
	7.5	12.2	0	19.7
Aver..........	7.5	12.3	0	
	7.6	12.4	0	20.0
	7.6	12.2	0	19.8
	*7.6	10.5	0	18.1

Continued on next page

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
		Contined		
	12.6	7.8	0	20.4
	12.6	7.6	0	20.2
	12.6	7.6	0	20.2
	12.6	7.6	0	20.2
	12.6	7.5	0.1	20.2
	12.6	8.0	0	20.6
	12.6	7.9	0	20.5
	12.6	7.9	0	20.5
	12.6	6.6	0	19.2
	12.6	7.0	0.1	19.7
Aver..........	12.6	7.5	0	
	12.5	7.2	0.6	20.3
	12.5	7.2	0	19.7
	12.5	6.6	0	19.1
	12.5	8.5	0	21.0
	12.5	7.6	0.1	20.2
	12.5	7.6	0	20.1
	12.5	7.5	0	20.0
	12.5	7.4	0	19.9
	12.5	7.3	0.5	20.3
	12.5	7.2	0	19.7
Aver..........	12.5	7.4	0.1	
	12.4	7.1	0	19.5
	12.4	7.0	0	19.4
	12.4	7.4	0	19.8
	12.4	7.4	0	19.8
	12.4	7.8	0	20.2
	12.4	7.7	0	20.1
	12.4	7.6	0	20.0
	12.4	7.6	0	20.0
	12.4	7.6	0.2	20.2
	12.4	7.6	0	20.0
	12.4	7.6	0	20.0
	12.4	8.0	0	20.4
	12.4	8.0	0	20.4
	12.4	8.0	0	20.4
	12.4	7.9	0	20.3
	12.4	8.2	0	20.6
	12.4	8.2	0	20.6
	12.4	8.2	0.3	20.9
	12.4	8.6	0	21.1
	12.4	7.6	0	20.0
Aver..........	12.4	7.8	0	
	12.3	8.2	0	20.5
	12.3	8.0	0.3	20.6
	12.3	7.8	0	20.1

Continued on next page

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

Continued

	CO_2	O	CO	Total
	7.6	12.6	0	20.2
	7.6	12.7	0	20.3
	7.6	12.4	0	20.0
	7.6	12.7	0	20.3
	7.6	11.5	0	19.1
	7.6	12.4	0	20.0
	7.6	12.5	0.1	20.2
	7.6	12.5	0	20.1
	7.6	12.4	0.2	20.2
	7.6	11.5	0.3	19.4
	7.6	12.6	0	20.2
	7.6	12.3	0	19.9
	7.6	12.6	0	20.2
	7.6	12.2	0	19.8
	*7.6	10.5	0	18.1
	†7.6	11.0	0.4	19.0
	7.6	12.9	0	20.5
	7.6	12.4	0	20.0
	7.6	11.8	0	19.4
	7.6	12.1	0	19.7
	7.6	12.0	0	19.6
	7.6	12.8	0	20.4
	7.6	11.7	0	19.3
	7.6	12.8	0	20.4
	7.6	12.7	0.3	20.6
	7.6	12.4	0	20.0
	7.6	12.9	0	20.5
	7.6	12.6	0	20.2
Aver........	7.6	12.2	0	
	7.7	12.4	0	20.1
	7.7	11.9	0	19.6
	†7.7	12.0	0.5	20.2
Aver........	7.7	12.1	0.2	
	7.8	11.8	0	19.6
	7.8	13.0	0	20.8
	7.8	11.5	0.2	19.5
	7.8	12.3	0	20.1
	7.8	11.9	0	19.7
	7.8	11.2	0	19.0
	7.8	12.0	0	19.8
	7.8	11.4	0.2	19.4
	7.8	13.0	0	20.8
	7.8	11.2	0	19.0
	7.8	12.6	0	20.4
	7.8	12.6	0	20.4
	7.8	12.4	0	20.2
	7.8	12.6	0	20.4
Aver.......	7.8	12.1	0	

TABLE 2—Continued

ARRANGED ACCORDING TO O

Continued

	O	CO_2	CO	Total
	12.3	7.6	0	19.9
	12.3	7.5	0	19.8
	12.3	7.4	0	19.7
	12.3	7.3	0.5	20.1
Aver..........	12.3	7.6	0.1	
	12.2	6.6	0	18.8
	12.2	7.1	0	19.3
	12.2	7.0	0	19.2
	12.2	6.9	0	19.1
	12.2	7.3	0	19.5
	12.2	7.3	0	19.5
	12.2	7.3	0	19.5
	12.2	7.6	0	19.8
	12.2	7.6	0	19.8
	12.2	7.5	0	19.7
	12.2	8.1	0	20.3
	12.2	8.2	0.1	20.5
	12.2	7.2	0	19.4
Aver..........	12.2	7.4	0	
	12.1	8.2	0	20.3
	12.1	8.0	0	20.1
	12.1	8.0	0.2	20.3
	12.1	7.6	0	19.7
	12.1	7.5	0	19.6
	12.1	7.4	0	19.5
	12.1	7.3	0	19.4
	12.1	7.2	0	19.3
Aver..........	12.1	7.7	0	
	12.0	7.2	0	19.2
	12.0	7.4	0	19.4
	12.0	7.4	0	19.4
	12.0	7.8	0	19.8
	12.0	7.7	0.5	20.2
	12.0	7.6	0	19.6
	12.0	8.0	0	20.0
	12.0	8.0	0.1	20.1
	12.0	7.9	0	19.9
	12.0	7.9	0	19.9
	12.0	8.2	0	20.2
	12.0	8.2	0	20.2
	12.0	8.4	0	20.4
	12.0	8.0	0	20.0
Aver.	12.0	7.1	0	
	11.9	8.4	0	20.3
	11.9	8.5	0	20.4
	11.9	8.2	0	20.1

Continued on next page

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO_2

CO_2	O	CO	Total
7.9	12.6	0	20.5
7.9	12.8	0	20.7
7 9	12.6	0	20.5
7.9	11.7	0.3	19.9
7.9	11.9	0.1	19.9
7.9	11.7	0	19.6
7.9	12.0	0	19.9
7.9	11.6	0.3	19.8
7.9	11.8	0.2	19.9
7.9	11.5	0	19.4
7.9	11.9	0.2	20.0
7.9	11.7	0.1	19.7
7.9	11.3	0.1	19.3
7.9	11.6	0	19.5
7.9	11.5	0	19.4
†*7.9	10 4	0.5	18 8
*7.9	10.6	0	18.5
7.9	12.4	0	20.3
7.9	11.9	0	19.8
7.9	12.0	0	19.9
Aver.......... 7.9	11.8	0 1	
8.0	11.9	0	19.9
8 0	11.6	0	19 3
8.0	11.8	0.3	20.1
8.0	11.9	0.1	20.0
*8.0	10.4	0.1	18.5
8.0	12.4	0	20.4
8.0	12.6	0	20.6
8.0	12.0	0	20.0
8.0	12.0	0.1	20.1
8.0	12.1	0.2	20 3
8.0	11.7	0	19.7
8.0	11.0	0.1	19.1
8.0	12.0	0	20.0
8.0	11.3	0	19.3
8.0	11.6	0	19.6
8.0	11.7	0	19 7
8.0	11.2	0	19.2
8.0	11.3	0	19.3
8.0	11.8	0	19.8
8.0	12.3	0.3	20.6
*8.0	10.0	0	18.0
8.0	11.4	0	19.4
8.0	11 8	0	19.8
8.0	11.8	0.1	19.9
8.0	12.4	0	20.4
8.0	12.4	0	20.4
8.0	11.9	0	19.9
8.0	11.8	0	19.8
8.0	12.1	0	20.1
8.0	11.4	0	19.4
Aver.......... 8.0	11.7	0	

TABLE 2—Continued

Arranged According to O

O	CO_2	CO	Total
	Continued		
11.9	8.2	0	20.1
11.9	8.0	0	19.9
11.9	8.0	0.1	20.0
11.9	8.0	0	19.9
11.9	7.9	0	19.8
11.9	7.9	0.2	20.0
11.9	7.9	0.1	19.9
11.9	7.8	0	19.7
11.9	7.7	0	19.6
11.9	7.4	0	19.3
11.9	7.3	0	19.2
11.9	7.2	0	19.1
11.9	7.0	0.1	19.0
11.9	8.9	0	20.8
Aver..........11.9	7.9	0	
11.8	7.8	0	19.6
11.8	7.6	0	19.4
11.8	8.0	0	19.8
11.8	8.0	0	19.8
11.8	8.0	0.1	19.9
11.8	8.0	0	19.8
11.8	8.0	0.3	20.1
11.8	7.9	0.2	19.9
11.8	8.3	0.3	20.4
11.8	8.3	0	20.1
11.8	8.2	0	20.0
11.8	8.2	0	20 0
11.8	8.4	0.3	20.5
11.8	8.4	0.2	20.4
11.8	8.4	0	20.2
11.8	8.8	0.3	20.9
Aver..........11.8	8.1	0.1	
11.7	8.7	0.1	20.5
11.7	8.4	0.2	20.3
11.7	8.3	0	20.0
11.7	8.3	0	20.0
11.7	8.1	0	19.8
11.7	8.0	0	19.7
11.7	8.0	0	19.7
11.7	7.9	0.1	19.7
11.7	7.9	0.3	19.9
11.7	7.9	0	19.6
11.7	7.6	0	19.3
11.7	7.5	0	19.2
Aver..........11.7	8.1	**0.1**	

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	8.1	11.7	0	19.8
	8.1	11.2	0.2	19.5
	*8.1	10.3	0.2	18.6
	8.1	12.2	0	20.3
	8.1	11.3	0.3	19.7
	†8.1	10.8	0.5	19.4
	8.1	11.5	0.1	19.7
Aver.	8.1	11.3	0.2	
	8.2	12.4	0.3	20.9
	8.2	12.0	0	20.2
	8.2	11.1	0.1	19.4
	*8.2	10.2	0.1	18.5
	†8.2	11.4	0.4	20.0
	†8.2	11.0	0.4	19.6
	8.2	11.2	0.2	19.6
	†8.2	11.4	0.5	20.1
	†8.2	11.1	0.4	19.7
	8.2	11.9	0	20.1
	8.2	11.8	0	20.0
	8.2	11.0	0	19.2
	8.2	12.4	0	20.6
	8.2	11.3	0	19.5
	8.2	12.1	0	20.3
	8.2	12.0	0	20.2
	8.2	12.2	0.1	20.5
	8.2	12.4	0	20.6
	8.2	11.6	0	19.8
	8.2	11.2	0	19.4
	8.2	11.8	0	20.0
	8.2	11.6	0	19.8
	†8.2	10.8	0.4	19.4
	8.2	10.7	0	18.9
	8.2	11.3	0	19.5
	8.2	12.1	0.3	20.6
	8.2	12.3	0	20.5
	8.2	11.6	0	19.8
	8.2	11.0	0.3	19.5
	8.2	12.3	0	20.5
	8.2	11.9	0	20.1
Aver..........	8.2	11.6	0.1	
	8.3	11.3	0	19.6
	8.3	11.8	0	20.1
	8.3	11.3	0	19.6
	8.3	11.7	0	20.0
	†8.3	11.5	0.4	20.2
	8.3	11.8	0.3	20.4

Continued on next page

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	11.6	8.0	0	19.6
	11.6	8.0	0	19.6
	11.6	7.9	0	19.5
	11.6	7.9	0.3	19.8
	11.6	9.1	0	20.7
	11.6	9.0	0	20.6
	11.6	9.0	0.2	20.8
	11.6	8.3	0	19.9
	11.6	8.2	0	19.8
	11.6	8.2	0	19.8
	11.6	8.2	0	19.8
	11.6	8.5	0	20.1
	11.6	8.4	0	20.0
	11.6	8.8	0	20.4
	11.6	8.8	0.2	20.6
	11.6	8.7	0.3	20.6
Aver..........	11.6	8.4	0.1	
	11.5	8.8	0.3	20.6
	11.5	8.9	0	20.4
	11.5	8.6	0.1	20.2
	11.5	8.5	0.2	20.2
	11.5	8.4	0	19.9
	11.5	8.3	0.4	20.2
	11.5	8.1	0.1	19.7
	11.5	7.9	0	19.4
	11.5	7.9	0	19.4
	11.5	6.7	0	18.2
	11.5	7.8	0.2	19.5
	11.5	7.6	0.3	19.4
	11.5	7.5	0	19.0
Aver..........	11.5	8.1	0.1	
	11.4	7.8	0.2	19.4
	11.4	8.0	0	19.4
	11.4	8.0	0	19.4
	11.4	8.2	0.5	20.1
	11.4	8.2	0.4	20.0
	11.4	8.5	0	19.9
	11.4	8.5	0	19.9
	11.4	8.4	0.2	20.0
	11.4	8.4	0	19.8
	11.4	8.4	0	19.8
	11.4	8.4	0	19.8
	11.4	8.4	0.2	20.0
	11.4	8.4	0	19.8
	11.4	8.9	0	20.3
	11.4	8.9	0	20.3
Aver..........	11.4	8.4	0.1	

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	Continued			
	8.3	11.7	0	20.0
	8.3	12.7	0	21.0
	8.3	11.1	0.2	19.6
	8.3	10.8	0	19.1
	8.3	9.7	0	18.0
	†8.3	10.1	0.8	19.2
	†8.3	10.5	0.5	19.3
	8.3	11.9	0.1	20.3
	8.3	11.6	0	19.9
Aver..........	8.3	11.3	0.2	
	8.4	10.8	0	19.2
	*8.4	10.2	0	18.6
	8.4	11.8	0	20.2
	8.4	11.3	0.1	19.8
	8.4	11.4	0.2	20.0
	8.4	11.4	0	19.8
	8.4	12.5	0.1	21.0
	8.4	11.6	0	20.0
	8.4	11.7	0.2	20.3
	8.4	11.8	0.2	20.4
	8.4	11.5	0	19.9
	8.4	11.9	0	20.3
	8.4	11.4	0	19.8
	8.4	11.0	0	19.4
	8.4	11.4	0	19.8
	8.4	11.0	0.5	19.9
	8.4	10.2	0.2	18.8
	†*8.4	9.9	0.5	18.8
	8.4	11.0	0	19.4
	8.4	11.0	0.2	19.6
	†8.4	11.3	0.4	20.1
	*8.4	9.9	0	18.3
	8.4	12.0	0	20.4
	8.4	11.4	0	19.8
	8.4	11.8	0.3	20.5
	8.4	11.4	0.2	20.0
	8.4	11.3	0	19.7
Aver..........	8.4	11.3	0.1	
	8.5	11.5	0.2	20.2
	8.5	12.5	0	21.0
	8.5	10.9	0	19.4
	8.5	12.3	0	20.8
	8.5	11.4	0	19.9
	8.5	11.6	0	20.1
	8.5	11.0	0.3	19.8
	8.5	11.9	0	20.4
	†8.5	10.3	0.3	19.1
	8.5	11.4	0	19.9
Aver..........	8.5	11.5	0.1	

TABLE 2—Continued

Arranged According to O

	O	CO_2	CO	Total
	11.3	8.7	0	20.0
	11.3	8.8	0	20.1
	11.3	8.9	0	20.2
	11.3	8.4	0	19.7
	11.3	8.4	0.4	20.1
	11.3	8.4	0.1	19.8
	11.3	8.3	0	19.6
	11.3	8.3	0	19.6
	11.3	8.2	0	19.5
	11.3	8.2	0	19.5
	11.3	8.1	0.3	19.7
	11.3	8.0	0	19.3
	11.3	8.0	0	19.3
	11.3	7.9	0.1	19.3
Aver..........	11.3	8.3	0.1	
	11.2	7.8	0	19.0
	*11.2	6.8	0	18.0
	*11.2	6.6	0	17.8
	11.2	8.2	0.2	19.6
	11.2	8.2	0	19.4
	11.2	9.0	0.2	20.4
	11.2	8.6	0	19.8
	11.2	8.6	0.2	20.0
	11.2	8.9	0	20.1
	11.2	8.8	0	20.0
	11.2	8.8	0	20.0
	11.2	8.6	0	19.8
	11.2	9.0	0	20.2
	11.2	7.8	0	19.0
Aver.........	11.2	8.3	0	
	11.1	8.9	0	20.0
	11.1	8.9	0.3	20.3
	11.1	8.9	0	20.0
	11.1	8.6	0	19.7
	11.1	8.6	0.1	19.8
	11.1	8.3	0.2	19.6
	11.1	8.2	0.4	19.7
	11.1	8.2	0.1	19.4
	11.1	9.3	0	20.4
	*11.1	6.8	0.1	18.0
Aver.......	11.1	8.5	0.1	
	11.0	8.2	0.3	19.5
	11.0	7.6	0.4	19.0
	11.0	9.4	0	20.4
	11.0	8.6	0	19.6
	11.0	8.6	0.2	19.8
	11.0	8.6	0	19.6
	11.0	8.6	0.4	20.0

Continued on next page

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	8.6	11.2	0	19.8
	8.6	10.5	0	19.1
	8.6	11.5	0.1	20.2
	8.6	11.2	0.2	20.0
	†8.6	11.0	0.4	20.0
	8.6	11.1	0.1	19.8
	†8.6	10.8	0.5	19.9
	8.6	10.7	0.2	19.5
	8.6	10.8	0	19.4
	8.6	11.0	0	19.6
	8.6	10.6	0	19.2
	8.6	12.4	0	21.0
	8.6	11.2	0	19.8
	8.6	11.1	0	19.7
	8.6	11.0	0	19.6
	8.6	11.0	0.2	19.8
Aver......	8.6	11.1	0.1	
	8.7	11.7	0.1	20.5
	8.7	11.0	0	19.7
	8.7	11.3	0	2.00
	8.7	10.2	0.1	19.0
	8.7	11.0	0.0	19.7
	8.7	10.7	0.3	19.7
	8.7	10.8	0	19.5
	8.7	11.6	0.3	20.6
	8.7	10.5	0	19.2
	8.7	10.4	0	19.1
	8.7	10.7	0.4	19.8
	8.7	10.6	0	09.3
Aver......	8.7	10.9	0.1	
	8.8	11.0	0	19.8
	8.8	11.6	0.2	20.6
	8.8	10.8	0.3	19.9
	8.8	10.8	0	19.6
	*8.8	10.2	0.3	18.3
	8.8	10.5	0.2	19.5
	°8.8	9.0	0	17.8
	8.8	11.2	0	20.0
	8.8	10.7	0.3	19.8
	8.8	10.9	0.2	19.9
	8.8	11.2	0	20.0
	8.8	11.6	0	20.4
	8.8	11.3	0	20.1
	†*8.8	9.2	0.6	18.6
	8.8	11.5	0.3	20.6
	8.8	11.8	0.3	20.9
	8.8	10.8	0.1	19.7
Aver.......	8.8	10.8	0.2	

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
		Continued		
	11.0	8.5	0.3	19.8
	11.0	8.4	0	19.4
	11.0	8.4	0.2	19.6
	11.0	8.4	0.5	19.9
	11.0	8.4	0	19.4
	11.0	8.7	0	19.7
	11.0	8.7	0	19.7
	11.0	8.8	0	19.8
	11.0	8.8	0.4	19.6
	11.0	9.0	0.3	20.3
	11.0	8.0	0.1	19.1
Aver......	11.0	8.5	0.3	
	10.9	9.0	0	19.9
	10.9	9.0	0	19.9
	10.9	9.2	0	20.1
	10.9	8.5	0	19.4
	10.9	8.8	0.2	19.9
Aver......	10.9	8.9	0	
	10.8	8.8	0.1	19.7
	10.8	8.8	0.3	19.9
	10.8	8.8	0	19.6
	10.8	8.7	0	19.5
	10.8	8.3	0	19.1
	10.8	8.2	0.4	19.4
	10.8	8.1	0.5	19.4
	10.8	8.6	0	19.4
	10.8	8.6	0.5	19.9
	10.8	8.4	0	19.2
	10.8	9.0	0	19.8
	10.8	9.0	0	19.8
	10.8	9.1	0.1	20.0
	10.8	9.1	0.2	20.1
Aver.......	10.8	8.7	0.2	
	10.7	9.2	0.3	20.2
	10.7	9.2	0	19.9
	10.7	9.1	0	19.8
	10.7	8.6	0.2	19.5
	10.7	9.4	0.1	20.2
	10.7	8.2	0	19.9
	10.7	8.8	0.3	19.8
	10.7	8.7	0.4	19.8
	10.7	8.7	0.3	19.7
	10.7	9.0	0	19.7
Aver.........	10.7	8.9	0.2	

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	8.9	11.1	0	20.0
	8.9	11.5	0	30.4
	8.9	11.9	0	20.8
	8.9	11.2	0	20.1
	8.9	11.4	0	20.3
	8.9	10.5	0.2	19.6
	†8.9	10.5	0.4	19 8
	8.9	11.1	0.3	20.3
	8.9	11.4	0	20.3
	*8.9	9.8	0.2	18.9
	8 9	10.6	0	19.5
	8.9	11.3	0	20.2
	8.9	10.3	0	19.2
	8.9	11.1	0	20.0
Aver.	8.9	11.0	0.1	
	9.0	11.2	0	20.2
	9.0	10.9	0	19 9
	9.0	10.7	0	19 7
	9.0	10.8	0	19.8
	9.0	10.5	0	19.5
	9.0	10.0	0	19.0
	9.0	10.8	0	19.8
	†9.0	9.8	0.4	19.2
	9 0	10.5	0	19.5
	9.0	10.6	0	19 6
	9.0	10.6	0.3	19 9
	†9.0	10.3	0 4	19.7
	9.0	11.0	0 3	20.3
	†9.0	9.6	0.4	19.0
	9 0	11.2	0.2	20.4
	9 0	11 6	0	20.6
	9.0	11.6	0.2	20.8
	9 0	10 9	0	19.9
	9.0	10.4	0	19.4
Aver.	9.0	10.7	0.1	
	9.1	10.7	0	19.8
	9.1	10 5	0.2	19.8
	†9.1	10.3	0.5	19.9
	9 1	10.8	0.1	20.0
	9.1	11.6	0	20 7
	9.1	10.2	0	19.3
	9.1	10.8	0 2	20.1
	*9.1	9 7	0	18.8
	9.1	10.5	0	19.6
	†9.1	10.3	0.5	19.9
	9.1	10.1	0.3	19.5
	9.1	10.6	0.1	19.8
Aver.	9.1	10.5	0.2	

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	*10.6	7.4	0	18 0
	*10.6	6.8	0	17.4
	10.6	7.9	0	19.5
	10.6	8.9	0	19.5
	10.6	9.4	0.2	20 2
	10.6	9.4	0.4	20.4
	10.6	8.6	0	19.2
	10.6	9.0	0	19.6
	10.6	9.0	0.3	19.9
	10.6	9.1	0.1	19.8
	10.6	9.2	0.1	19.9
	10.6	9.2	0	19.8
	10.6	9.2	0.2	20.0
	10.6	8 7	0	19.3
	*10.6	7.2	0	17.8
Aver..	10.6	8.6	0.1	
	10.5	9.0	0	19.5
	10.5	9.0	0	19.5
	10.5	9.1	0.2	19.8
	10.5	9.1	0	19.6
	10.5	9 2	0.1	19.8
	10 5	8.6	0	19.1
	10.5	9.4	0 3	20.2
	10.5	9.3	0.4	20.2
	10.5	8.3	0.5	19.3
	*10.5	7.6	0	18.1
	10 5	8.9	0 2	19.6
	10.5	8.9	0.4	19 8
	10.5	8.8	0.2	19.5
	10.5	8 7	0	19.2
Aver.......	10.5	8.9	0.2	
	10.4	8 0	0.1	18.5
	*10.4	7.9	0.5	18.8
	10.4	8.7	0	19.1
	10.4	9.3	0.5	20.2
	10.4	9 4	0	19.8
	10.4	9.5	0	19.9
	10.4	9.6	0.2	20.2
	10.4	9.2	0.2	20.0
	10.4	9.2	0	19.6
	10.4	9.2	0.2	19.8
	10 4	9.0	0	19.4
Aver	10.4	9.0	0.2	
	10.3	9.2	0	19.5
	10.3	9 2	0.3	19.8
	10.3	9.1	0.5	19.9
	10.3	9.1	0.5	19.9
	10.3	9.0	0.4	19.7

Continued on next page

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO₂

	CO_2	O	CO	Total
	9.2	10.7	0	19.9
	9.2	10.6	0.1	19.9
	9.2	10.4	0.2	19.8
	9.2	10.6	0	19.8
	9.2	10.2	0.1	19.4
	9.2	10.5	0.1	19.8
	9.2	10.7	0.3	20.2
	9.2	10.6	0.2	20.0
	9.2	10.4	0	19.6
	9.2	10.9	0	20.1
	9.2	10.4	0.2	19.8
	9.2	10.3	0	19.5
	9.2	10.3	0.3	19.8
	*† 9.2	9.2	0.4	18.8
Aver....	9.2	10.4	0.1	
	† 9.3	9.8	0.4	19.5
	* 9.3	8.7	0.2	18.2
	9.3	10.0	0.2	19.5
	† 9.3	10.5	0.4	20.2
	† 9.3	10.4	0.5	20.2
	9.3	10.2	0	19.5
	9.3	10.3	0.3	19.9
	* 9.3	9.3	0	18.6
	† 9.3	9.8	0.5	19.6
	9.3	11.1	0	20.4
	9.3	10.3	0	19.6
Aver......	9.3	10.0	0.2	
	9.4	9.7	0	19.1
	9.4	9.6	0	19.0
	9.4	10.9	0.1	20.4
	9.4	10.4	0	19.8
	9.4	10.6	0.2	20.2
	9.4	11.0	0	20.4
	9.4	9.4	0.3	19.1
	9.4	10.5	0.3	20.2
	9.4	9.9	0.3	19.6
	† 9.4	10.6	0.4	20.4
	9.4	10.7	0.1	20.2
	† 9.4	10.2	0.4	20.0
	* 9.4	9.5	0	18.9
	9.4	10.1	0.1	19.6
	9.4	9.6	0.2	19.2
	9.4	9.6	0.3	19.3
Aver......	9.4	10.1	0.2	

TABLE 2—Continued

Arranged According to O

	O	CO_2	CO	Total
		Continued		
	10.3	8.5	0.3	19.1
	10.3	9.3	0.3	19.9
	10.3	9.3	0	19.6
	10.3	9.5	0.2	20.0
	10.3	9.6	0	19.9
	10.3	8.1	0.2	18.6
	10.3	8.9	0	19.2
Aver......	10.3	9.1	0.2	
	* 10.2	8.2	0.1	18.5
	10.2	9.3	0	19.5
	10.2	8.7	0.1	19.0
	10.2	8.8	0.3	19.9
	10.2	9.6	0	19.8
	10.2	10.2	0.6	21.0
	*10.2	8.4	0.2	18.8
	10.2	9.1	0	19.3
	10.2	9.2	0	19.4
	10.2	8.4	0	18.6
Aver....	10.2	9.0	0.1	
	10.1	9.1	0.3	19.5
	10.1	9.4	0.1	19.6
	10.1	8.3	0.8	19.2
Aver.......	10.1	8.9	0.4	
	*10.0	8.0	0	18.0
	10.0	9.7	0.5	20.0
	10.0	9.6	0	19.6
	10.0	9.3	0.2	19.5
	10.0	10.2	0.1	20.3
	10.0	10.2	0	20.2
	10.0	9.0	0	19.0
Aver.	10.0	9.4	0.1	
	9.9	9.4	0.3	19.6
	9.9	9.5	0.4	19.8
	9.9	9.5	0.1	19.5
	9.9	9.6	0.2	19.7
	9.9	10.2	0.6	20.7
	9.9	10.2	0	20.1
	9.9	9.8	0.2	19.9
	* 9.9	8.4	0.5	18.8
	9.9	8.4	0	19.3
Aver.......	9.9	9.4	0.3	
	9.8	9.8	0	19.6
	9.8	9.0	0.4	19.2
	9.8	9.6	0.1	19.5
	9.8	9.6	0	19.4

Continued on next page

U. S. Government Tests

TABLE 1—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	†9.5	9.3	0.5	19.3
	†9.5	9.9	0.4	19.8
	*9.5	8.5	0	18.0
	†9.5	9.3	0.6	19.4
	*9.5	8.9	0.1	18.5
	9.5	10.4	0	19.9
	†9.5	9.3	0.5	19.3
	9.5	9.9	0.1	19.5
	9.5	10.3	0.2	20.0
Aver.......	9.5	9.4	0.3	
	9.6	9.6	0	19.2
	9.6	9.8	0.1	19.5
	9.6	9.8	0	19.4
	9.6	10.0	0	19.6
	†9.6	9.6	0.8	20.0
	9.6	9.9	0.2	19.7
	9.6	9.4	0.2	19.2
	9.6	10.2	0	19.8
	9.6	10.3	0	19.9
	9.6	10.4	0.2	20.2
Aver.......	9.6	9.9	0.2	
	†9.7	10.0	0.5	20.2
	†9.7	9.5	0.4	19.6
Aver.......	9.7	9.8	0.5	
	9.8	9.6	0.2	19.6
	†9.8	9.3	0.4	19.7
	9.8	9.9	0.2	19.9
	9.8	9.8	0	19.6
	9.8	9.7	0.3	19.8
	9.8	9.7	0	19.5
	†9.8	9.2	0.4	19.4
	*9.8	8.2	0.3	18.3
Aver.......	9.8	9.4	0.2	
	9.9	8.9	0.6	19.4
	9.9	9.7	0.1	19.7
	†9.9	9.7	0.3	19.9
	†9.9	8.8	0.4	19.1
	*9.9	8.0	0	17.9
	†9.9	8.2	1.4	19.5
	9.9	9.6	0	19.5
Aver.......	9.9	9.0	0.4	

TABLE 2—Continued

Arranged According to O

	O	CO_2	CO	Total
		Continued		
	9.8	9.3	0.5	19.6
	9.8	9.3	0.4	19.5
	*9.8	8.9	0.2	18.9
Aver.......	9.8	9.4	0.3	
	9.7	9.4	0	19.1
	*9.7	9.1	0	18.8
	*9.7	8.3	0	18.0
	9.7	9.8	0.3	19.8
	9.7	9.8	0	19.5
	9.7	9.9	0.1	19.7
	9.7	9.9	0.3	19.9
Aver.......	9.7	9.5	0.1	
	9.6	10.1	0.3	20.0
	9.6	9.9	0	19.5
	9.6	9.8	0.2	19.6
	9.6	9.6	0.0	19.2
	9.6	9.4	0.2	19.2
	9.6	9.4	0.3	19.3
	9.6	9.4	0	19.0
	9.6	9.6	0.8	20.0
	9.6	9.0	0.4	19.0
Aver.......	9.6	9.6	0.2	
	9.5	10.1	0.4	20.0
	9.5	10.1	0	19.6
	9.5	9.7	0.4	19.6
	9.5	10.4	0	19.9
Aver.......	9.5	10.1	0.2	
	9.4	9.4	0.3	19.1
	9.4	9.6	0.2	19.2
	9.4	10.4	0.1	19.9
	9.4	10.2	0	19.6
	9.4	10.0	0.2	19.6
	9.4	10.0	0	19.4
	9.4	10.0	0.3	19.7
Aver.......	9.4	9.9	0.2	
	9.3	9.8	0.4	19.7
	9.3	10.5	0.2	20.0
	9.3	10.5	0.4	20.2
	9.3	9.5	0.5	19.3
	*9.3	9.3	0	18.6
	9.3	9.5	0.5	19.3
Aver.......	9.3	9.9	0.3	

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	10.0	9.4	0	19.4
	†10.0	9.4	0.3	19.7
	10.0	9.2	0	19.2
	†10.0	9.0	0.3	19.3
	*10.0	8.6	0	18.6
	10.0	9.4	0.2	19.6
	†10.0	9.2	0.4	19.6
	†10.0	9.0	0.3	19.3
Aver.......	10.0	9.2	0.2	
	*10.1	7.0	0.2	17.3
	10.1	9.6	0.3	20.0
	†10.1	8.9	1.6	20.6
	†10.1	8.6	2.1	20 8
	10.1	9.5	0	19.6
	10.1	9.0	0.3	19.4
	†10.1	9.5	0.4	20.0
	†*10.1	8.2	0.4	18.7
Aver.......	10.1	8.8	0.7	
	10.2	10.0	0	20.2
	10.2	9.9	0	20.1
	10.2	10.0	0.1	20.3
	10.2	9.4	0	19.6
	†10.2	9.9	0.6	20.7
	†10.2	10.2	0.6	21.0
Aver.......	10.2	9.9	0.2	
	*10.3	7.7	0	18 0
	†10.4	8.9	0.5	19 8
	†10.4	8.6	1.4	20 4
	10.4	9.5	0	19.9
	†10 4	9.0	0.5	19.5
	†10.4	8 2	0.5	19.1
	10.4	8.9	0.2	19.5
	10.4	9.4	0.1	19.9
Aver.......	10.4	8.9	0.5	
	10.5	9.3	0.2	20.0
	†10.5	9.3	0.4	20.2
	†*10 5	7.7	0.6	18.8
	†10.5	8.6	0.5	19.6
Aver...	10.5	8.7	0.4	
	10.6	0	0	19.6
	10.7	9.1	0.2	20.0
	†10.7	7.9	0.9	19.5
	10.7	8.1	1.1	19.9
Aver.......	10.7	8.4	0.7	

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	*9.2	8.8	0.6	18.6
	9 2	10.0	0 4	19.6
	*9.2	7.1	0.3	16.7
	9.2	10.0	0	19.2
	9.2	9.8	0.4	19.4
	*9.2	9.2	0.4	18 8
Aver.......	9.2	9.2	0.4	
	9.1	10.7	0.2	20.0
	9.1	10.1	0.3	20.5
Aver.......	9 1	10.4	0.2	
	*9.0	8.8	0	17.8
	9.0	10.6	0	19.6
	9.0	10.4	0.5	19.5
	9.0	10.1	0.3	19.4
	9.0	10.0	0.3	19.3
	9.0	10.0	0.3	19.3
Aver'......	9.0	10.0	0.2	
	8.9	9.9	0.6	19.4
	8.9	10.1	1.6	19.7
	8.9	10.4	0.5	19.8
	8.9	10.4	0.2	19.5
	* 8.9	9.5	0.1	18.5
Aver.......	8.9	10.0	0.6	
	8.8	9.9	0.4	19.1
	8.8	11.0	0.5	20.3
	8.8	11.0	0	19.8
Aver.......	8.8	10.6	0.3	
	* 8.7	9.3	0.2	18.2
	8.7	10.8	0	19.5
Aver.......	8.7	10.0	0.1	
	8.6	10.1	2.1	20.8
	8.6	10.8	0	19.4
	8.6	10.8	0	19.4
	8.6	10.5	0.5	19.6
	8.6	10.4	1.4	20.4
	* 8.6	10.0	0	18.6
Aver.......	8.6	10.4	0.7	
	* 8.5	9.5	0	18.0
	8.3	10.8	0.1	19.2

U. S. GOVERNMENT TESTS

TABLE 1—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	10.8	8.6	0	19.4
	10.8	8.6	0	19.4
	10.8	8.7	0	19.5
	10.8	8.3	0.1	19.2
Aver......	10.8	8.6	0	
	10.9	7.9	0.3	19.1
	†11.0	8.8	0.5	20.3
	11.0	8.8	0	19.8
Aver......	11.0	8.8	0.3	
	11.1	8.1	0.2	19.4
	11.1	9.1	0.3	20.5
Aver.......	11.1	8.6	0.3	
	†11.4	7.9	0.4	19.7

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	8.2	10.4	0.5	19.1
	8.2	10.1	0.4	18.7
	8.2	9.9	1.4	19.5
	8.2	9.8	0.3	18.3
Aver......	8.2	10.0	0.6	
	8.1	10.7	1.1	19.9
	8.1	11.1	0.2	19.4
Aver......	8.1	10.9	0.6	
	8.0	9.9	0	17.9
	7.9	10.7	0.9	19.5
	7.9	10.4	0.4	19.7
Aver........	7.9	11.0	0.6	
	* 7.7	10.5	0.6	18.8
	* 7.0	10.1	0.2	17.3

LOCOMOTIVE TESTS[1]

TABLE 3

ARRANGED ACCORDING TO CO_2

CO_2	O	CO	Total
10.16	8.49	0.13	18.78
11.10	7.84	0.23	19.17
11.15	7.52	0.20	18.87
11.45	6.92	0	18.37
11.46	7.49	0.1	19.05
11.50	7.08	0.17	18.75
11.78	6.74	0.30	18.82
11.96	7.00	0.23	19.19
11.96	7.07	0.14	19.17
12.05	6.93	0.15	19.13
12.20	6.94	0.05	19.19
12.45	5.87	0.22	18.54
13.57	4.49	0.20	18.26
13.87	4.75	0.25	18.87

TABLE 4

ARRANGED ACCORDING TO O

O	CO_2	CO	Total
8.49	10.16	0.13	18.78
7.84	11.10	0.23	19.17
7.52	11.15	0.20	18.87
7.49	11.46	0.1	19.05
7.08	11.50	0.17	18.75
7.07	11.96	0.14	19.17
7.00	11.96	0.23	19.19
6.94	12.20	0.05	19.19
6.93	12.05	0.15	19.13
6.92	11.45	0	18.37
6.74	11.78	0.30	18.82
5.87	12.45	0.22	18.54
4.75	13.87	0.25	18.87
4.49	13.57	0.20	18.26

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[1] Bulletin No, 367, U. S. Geological Survey, The Significance of Draft in Steam Boiler Practice.

Six Hour Average Samples

TABLE 5

Arranged According to CO_2

	CO_2	O	CO	Total
	8.2	11.4	0	19.6
	8.5	11.3	0	19.8
	8.8	10.6	0	19.4
	9.0	10.3	0	19.3
	9.0	10.2	0	19.2
Aver.......	9.0	10.3	0	
	9.2	10.1	0	19.3
	9.2	10.1	0	19.3
Aver.......	9.2	10.1	0	
	9.3	10.3	0	19.6
	9.3	9.8	0	19.1
Aver.......	9.3	10.1	0	
	9.5	10.3	0	19.8
	9.6	9.6	0	19.2
	9.7	10.1	0	19.8
	9.8	9.8	0	19.6
	9.8	9.7	0	19.5
	9.8	9.7	0	19.5
Aver.......	9.8	9.7	0	
	† 9.9	8.9	0.4	19.2
	10.0	9.9	0	19.9
	10.0	9.1	0	19.1
	10.0	9.0	0	19.0
	10.0	9.0	0	19.0
	10.0	9.5	0	19.5
	10.0	9.3	0	19.3
	10.0	9.3	0	19.3
Aver.......	10.0	9.3	0	
	10.1	9.1	0	19.2
	10.1	9.8	0	19.9
Aver.......	10.1	9.5	0	
	10.2	9.4	0	19.6
	10.2	9.3	0	19.5
	10.2	9.2	0	19.4
	10.2	9.1	0	19.3
Aver.......	10.2	9.3	0	

TABLE 6

Arranged According to O

	O	CO_2	CO	Total
	11.4	8.2	0	19.6
	11.3	8.0	0	19.3
	11.3	8.5	0	19.8
Aver.......	11.3	8.3	0	
	10.6	8.8	0	19.4
	10.3	9.0	0	19.3
	10.3	9.3	0	19.6
	10.4	9.5	0	19.8
Avser......	10.3	9.3	0	
	10.2	9.0	0	19.2
	10.1	9.2	0	19.3
	10.1	9.2	0	19.3
	10.1	9.7	0	19.8
Aver...	10.1	9.4	0	
	9.9	10.0	0	19.9
	9.8	9.3	0	19.1
	9.8	9.8	0	19.6
	9.8	10.1	0	19.9
Aver.......	9.8	9.7	0	
	9.7	9.8	0	19.5
	9.7	9.8	0	19.5
Aver.......	9.7	9.8	0	19.5
	9.6	9.6	0	19.2
	9.5	10.0	0	19.5
	9.4	10.2	0	19.6
	9.4	10.3	0	19.7
	9.4	10.6	0	20.0
Aver.......	9.4	10.4	0	
	9.3	10.0	0	19.3
	9.3	10.0	0	19.3
	9.3	10.2	0	19.5
	9.3	10.3	0	19.6
	9.3	10.4	0	19.7
	9.3	10.4	0	19.7
	9.3	10.5	0	19.8
Aver.......	9.3	10.3	0	

Six Hour Average Samples

TABLE 5—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	10.3	9.0	0	19.3
	10.3	9.0	0	19.3
	10.3	9.1	0	19.4
	10.3	9.1	0	19.4
	10.3	9.2	0	19.5
	10.3	8.6	0.1	19.0
	10.3	8.7	0	19.0
	10.3	8.7	0	19.0
	10.3	8.8	0	19.1
	10.3	9.4	0	19.7
	10.3	9.2	0	19.5
	10.3	9.3	0	19.6
Aver.......	10.3	9.0	0	
	10.4	9.3	0	19.7
	10.4	9.3	0	19.7
	10.4	8.7	0	19.1
	10.4	8.9	0	19.3
Aver.......	10.4	9.1	0	
	10.5	8.9	0	19.4
	10.5	9.0	0	19.5
	10.5	9.3	0	19.8
Aver.......	10.5	9.1	0	
	10.6	9.4	0	20.0
	10.6	9.2	0	19.8
	10.6	8.4	0	19.0
Aver.......	10.6	9.0	0	
	10.7	8.3	0	19.0
	10.7	8.8	0	19.5
	10.7	8.6	0	19.3
	10.7	8.3	0	19.0
Aver.......	10.7	8.5	0	
	10.8	8.4	0	19.2
	10.8	8.4	0	19.2
Aver.......	10.8	8.4	0	
	10.9	8.5	0	19.4
	10.9	8.2	0.2	19.1
Aver.......	10.9	8.4	0.1	
	11.0	8.8	0	19.8
	11.0	8.7	0	19.7
	11.0	8.1	0	19.1
	11.0	8.2	0	19.2
	11.0	8.0	0	19.0

Continued on next page

TABLE 6—Continued

Arranged According to O

	O	CO_2	CO	Total
	9.2	10.2	0	19.4
	9.2	10.3	0	19.5
	9.2	10.3	0	19.5
	9.2	10.6	0	19.8
Aver.......	9.2	10.4	0	
	9.1	10.0	0	19.1
	9.1	10.1	0	19.2
	9.1	10.2	0	19.3
	9.1	10.3	0	19.4
	9.1	10.3	0	19.4
Aver.......	9.1	10.2	0	
	9.0	10.0	0	19.0
	9.0	10.0	0	19.0
	9.0	10.3	0	19.3
	9.0	10.3	0	19.3
	9.0	10.5	0	19.5
Aver.......	9.0	10.2	0	
	8.9	9.9	0.4	19.2
	8.9	10.4	0	19.3
	8.9	10.5	0	19.4
Aver......	8.9	10.3	0.2	
	8.8	10.3	0	19.1
	8.8	10.7	0	19.5
	8.8	11.0	0	19.8
Aver.......	8.8	10.7	0	
	8.7	10.3	0	19.0
	8.7	10.3	0	19.0
	8.7	10.4	0	19.1
	8.7	11.0	0	19.7
Aver.....	8.7	10.5	0	
	8.6	10.3	0.1	19.0
	8.6	10.7	0	19.3
Aver........	8.6	10.5	0.1	
	8.5	10.9	0	19.4
	8.5	11.0	0	19.5
	8.5	11.0	0	19.5
	8.5	11.0	0	19.5
	8.5	11.1	0	19.6
Aver.......	8.5	11.0	0	
	8.4	10.6	0	19.0
	8.4	10.8	0	19.2
	8.4	10.8	0	19.2
	8.4	11.0	0	19.4
	8.4	11.0	0	19.4
	8.4	11.4	0	19.8
Aver.......	8.4	10.9	0	

SIX HOUR AVERAGE SAMPLES

TABLE 5—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
		Continued		
	11.0	8.0	0	19.0
	11.0	8.4	0	19.4
	11.0	8.4	0	19.4
	11.0	8.5	0	19.5
	11.0	8.5	0	19.5
	11.0	8.5	0	19.5
	11.0	8.3	0	19.3
	11.0	8.2	0	19.2
Aver.......	11.0	8.4	0	
	11.1	8.2	0	19.3
	11.1	8.2	0	19.3
	11.1	8.5	0	19.6
	11.1	7.9	0	19.0
Aver.......	11.1	8.2		
	11.2	8.0	0	19.2
	11.2	8.0	0	19.2
	11.2	8.0	0	19.2
Aver.......	11.2	8.0	0	
	11.3	8.2	0	19.5
	11.3	8.2	0	19.5
	11.3	7.8	0	19.1
	11.3	7.7	0	19.0
Aver.......	11.3	8.0	0	
	11.4	7.6	0	19.0
	11.4	7.7	0	19.1
	11.4	8.4	0	19.8
Aver.......	11.4	7.9	0	
	11.5	7.8	0	19.3
	11.5	7.8	0	19.3
	11.5	7.5	0	19.0
	11.5	7.5	0	19.0
	11.5	7.9	0	19.4
Aver.......	11.5	7.7	0	
	11.6	7.4	0	19.0
	11.6	7.4	0	19.0
	11.6	8.3	0	19.9
	11.6	7.9	0	19.5
	11.6	7.8	0	19.4
Aver.......	11.6	7.9	0	
	11.7	7.6	0	19.3
	11.7	7.6	0	19.3
	11.7	8.1	0	19.8
	11.7	7.8	0	19.5
	11.7	7.4	0	19.1
Aver.......	11.7	7.7	0	

TABLE 6—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	8.3	10.0	0	19.3
	8.3	10.7	0	19.0
	8.3	10.7	0	19.0
	8.3	11.0	0	19.3
	8.3	11.6	0	19.9
	8.3	12.2	0.3	20.8
Aver.......	8.3	11.0	0.1	
	8.2	11.0	0	19.2
	8.2	11.0	0	19.2
	8.2	11.1	0	19.3
	8.2	11.1	0	19.3
	8.2	11.3	0	19.5
	8.2	11.3	0	19.5
Aver.......	8.2	11.1	0	
	8.1	11.0	0	19.1
	8.1	11.7	0	19.8
	8.1	11.8	0	19.9
Aver.......	8.1	11.5	0	
	8.0	11.0	0	19.0
	8.0	11.0	0	19.0
	8.0	11.2	0	19.2
	8.0	11.2	0	19.2
	8.0	11.2	0	19.2
	8.0	11.8	0	19.8
Aver.......	8.0	11.2	0	
	7.9	11.1	0	19.0
	7.9	11.5	0	19.4
	7.9	11.6	0	19.5
Aver.......	7.9	11.4	0	
	7.8	11.3	0	19.1
	7.8	11.5	0	19.3
	7.8	11.5	0	19.3
	7.8	11.6	0	19.4
	7.8	11.7	0	19.5
	7.8	11.8	0	19.6
	7.8	12.1	0	19.9
Aver......	7.8	11.6	0	
	7.7	11.3	0	19.0
	7.7	11.4	0	19.1
	7.7	11.9	0	19.6
	7.7	12.1	0	19.8
	7.7	13.3	0	21.0
Aver.......	7.7	12.0	0	

SIX HOUR AVERAGE SAMPLES

TABLE 5—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	11.8	7.2	0	19.0
	11.8	7.3	0	19.1
	11.8	7.3	0	19.1
	11.8	8.1	0	19.9
	11.8	8.0	0	19.8
	11.8	7.8	0	19.6
Aver.......	11.8	7.6	0	
	11.9	7.7	0	19.6
	11.9	7.3	0	19.2
Aver.......	11.9	7.5	0	
	†12.0	6.6	0.4	19.0
	12.0	6.9	0.1	19.0
	12.0	7.0	0	19.0
Aver.......	12.0	6.8	0.2	
	12.1	7.8	0	19.9
	12.1	7.6	0	19.7
	12.1	7.1	0	19.8
	12.1	7.2	0	19.2
	12.1	7.2	0	19.3
	12.1	7.3	0	19.4
Aver.......	12.1	7.5	0	
	12.2	7.3	0	19.5
	12.2	6.8	0	19.0
	12.2	6.9	0	19.1
	12.2	7.0	0	19.2
	12.2	7.4	0	19.6
	12.2	7.6	0	19.8
	12.2	7.6	0	19.8
	12.2	8.3	0.3	20.8
Aver.......	12.2	7.4	0	
	12.3	6.6	0.1	19.0
	12.3	7.0	0	19.3
Aver.......	12.3	6.8	0.1	
	12.4	7.2	0	19.6
	12.4	7.2	0	19.6
Aver.......	12.4	7.2	0	
	12.5	7.1	0	19.6
	12.5	6.5	0	19.0
	12.5	7.0	0	19.5
Aver.......	12.5	6.9	0	19.4
	12.6	6.6	0	19.2
	12.6	6.5	0	19.1
	12.6	7.2	0	19.8
Aver.......	12.6	6.8	0	

TABLE 6—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	7.6	11.4	0	19.0
	7.6	11.7	0	19.3
	7.6	11.7	0	19.3
	7.6	12.1	0	19.7
	7.6	12.2	0	19.8
	7.6	12.2	0	19.8
Aver.......	7.6	11.9	0	
	7.5	11.5	0	19.0
	7.5	11.5	0	19.0
Aver.......	7.5	11.5	0	
	7.4	11.6	0	19.0
	7.4	11.7	0	19.1
	7.4	12.2	0	19.6
Aver.......	7.4	11.8	0	
	7.3	11.8	0	19.1
	7.3	11.8	0	19.1
	7.3	11.9	0	19.2
	7.3	12.1	0	19.4
	7.3	12.2	0	19.5
Aver.......	7.3	12.0	0	
	7.2	11.8	0	19.0
	7.2	12.1	0	19.3
	7.2	12.4	0	19.6
	7.2	12.6	0	19.8
	7.2	12.4	0	19.6
Aver.......	7.2	12.3		
	7.1	12.1	0	19.2
	7.1	12.5	0	19.6
Aver.......	7.1	12.3		
	7.0	12.0	0	19.0
	7.0	12.2	0	19.2
	7.0	12.3	0	19.3
	7.0	12.5	0	19.5
Aver.......	7.0	12.3	0	
	6.9	12.0	0.1	19.0
	6.9	12.2	0	19.1
Aver.......	6.9	12.1	0.1	
	6.8	12.2	0	19.0
	6.8	12.7	0	19.5
Aver.......	6.8	12.5	0	
	6.6	12.0	0.4	19.0
	6.6	12.3	0.1	19.0
	6.6	12.6	0	19.2
Aver.......	6.6	12.3	0.2	

Six Hour Average Samples

TABLE 1—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	12.7	6.3	0	19.0
	12.7	6.8	0	19.5
Aver.......	12.7	6.6	0	
	12.8	6.2	0	19.0
	12.8	6.2	0	19.0
Aver.......	12.8	6.2	0	
	13.0	6.1	0	19.1
	13.0	6.1	0	19.1
	13.0	6.4	0	19.4
	13.0	6.2	0	19.2
Aver.......	13.0	6.2	0	
	13.1	6.0	0	19.1
	13.2	6.4	0	19.6
	13.2	5.9	0	19.1
	13.2	5.6	0.2	19.0
Aver.......	13.2	6.0	0.1	
	13.3	6.0	0	19.3
	13.3	5.5	0.2	19.0
	13.3	7.7	0	21.0
Aver.......	13.3	6.4	0.1	
	13.5	6.1	0	19.6
	13.6	5.1	0.3	19.0
	13.7	5.5	0	19.2
	13.8	5.2	0	19.0
	13.8	6.0	0	19.8
	13.8	6.0	0	19.8
Aver.......	13.8	5.7	0	

TABLE 1—Continued

Arranged According to O

	O	CO_2	CO	Total
	6.5	12.5	0	19.0
	6.5	12.6	0	19.1
Aver.......	6.5	12.6	0	
	6.4	13.0	0	19.4
	6.4	13.2	0	19.6
Aver........	6.4	13.1	0	
	6.3	12.7	0	19.0
	6.2	12.8	0	19.0
	6.2	12.8	0	19.0
	6.2	13.0	0	19.2
Aver.......	6.2	12.9	0	
	6.1	13.0	0	19.1
	6.0	13.3	0	19.3
	6.0	12.8	0	18.8
	6.0	12.8	0	18.8
Aver.......	6.0	13.0	0	
	5.9	13.1	0	19.0
	5.9	13.2	0	19.1
Aver.......	5.9	13.2	0	
	5.6	13.2	0.2	19.0
	5.5	13.3	0.2	19.0
	5.5	13.7	0	19.2
Aver.......	5.5	13.5	0.1	
	5.2	13.8	0	19.0
	5.1	13.6	0.3	19.0

Six Hour Average Samples

TABLE 7

Arranged According to CO_2

	CO_2	O	CO	Total
	8.0	10.5	0.1	18.6
	8.0	10.7	0.1	18.8
	8.0	10.1	0.1	18.2
Aver.......	8.0	10.4	0.1	
	8.5	9.9	0.1	18.5
	8.7	9.8	0.1	18.6
	9.0	9.4	0.2	18.6
	9.2	9.4	0.1	18.7
	†9.3	8.7	0.4	18.4
	9.4	8.9	0.2	18.5
	9.5	8.5	0	18.0
	9.6	9.3	0	18.9
	9.6	8.8	0.2	18.6
	9.6	9.3	0	18.9
Aver.......	9.6	9.1	0.1	
	9.7	8.9	0.2	18.8
	†9.7	8.1	0.4	18.2
	9.7	9.0	0.1	18.8
Aver.......	9.7	8.7	0.2	
	†9.8	8.2	0.4	18.4
	9.8	8.8	0.1	18.7
	9.8	9.1	0	18.9
Aver.......	9.8	8.7	0.2	
	9.9	8.9	0.1	18.9
	9.9	8.8	0.1	18.8
Aver.......	9.9	8.9	0.1	
	10.0	8.3	0	18.3
	†10.0	8.1	0.3	18.4
	†10.0	8.1	0.3	18.4
	10.0	8.7	0.1	18.8
	10.0	8.7	0.1	18.8
Aver.......	10.0	8.4	0.2	
	†10.1	7.9	0.4	18.4
	†10.1	7.5	0.5	18.1
	†10.1	7.7	0.4	18.2
Aver.......	10.1	7.7	0.4	

TABLE 8

Arranged According to O

	O	CO_2	CO	Total
	10.7	8.0	0.1	18.8
	10.5	8.0	0.1	18.6
	10.1	8.0	0.1	18.2
	9.9	8.5	0.1	18.5
	9.8	8.7	0.1	18.6
	9.4	9.0	0.2	18.6
	9.4	9.2	0.1	18.7
Aver.......	9.4	9.1	0.2	
	9.3	9.6	0	18.9
	9.3	9.6	0	18.9
Aver.......	9.3	9.6	0	
	9.1	9.8	0	18.9
	9.0	9.7	0.1	18.8
	8.9	9.4	0.2	18.5
	8.9	9.7	0.2	18.8
	8.9	9.9	0.1	18.9
Aver.......	8.9	9.7	0.2	
	8.8	9.6	0.2	18.6
	8.8	9.8	0.1	18.7
	8.8	9.9	0.1	18.8
Aver.......	8.8	9.8	0.1	
	8.7	9.3	0.4	18.4
	8.7	10.0	0.1	18.8
	8.7	10.0	0.1	18.8
Aver.......	8.7	9.8	0.2	
	8.6	10.2	0.1	18.9
	8.5	9.5	0	18.0
	8.4	10.4	0.1	18.9
	8.3	10.5	0.1	18.9
	8.2	9.8	0.4	18.4
	8.2	10.2	0	18.4
	8.2	10.4	0.2	18.8
Aver.......	8.2	10.1	0.2	

SIX HOUR AVERAGE SAMPLES

TABLE 7—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	10.2	8.6	0.1	18.9
	†10.2	7.8	0.3	18.3
	10.2	8.2	0	18.4
Aver.......	10.2	8.2	0.1	
	10.3	8.0	0.2	18.5
	10.3	8.0	0.2	18.5
Aver.......	10.3	8.0	0.2	
	10.4	8.1	0.2	18.7
	10.4	8.2	0.2	18.8
	10.4	8.4	0.1	18.9
Aver.......	10.4	8.2	0.2	
	10.5	8.0	0.2	18.7
	10.5	7.8	0.2	18.5
	10.5	8.3	0.1	18.9
Aver.......	10.5	8.0	0.2	
	10.6	8.0	0.1	18.7
	10.6	7.7	0.2	18.5
Aver.......	10.6	7.9	0.2	
	†10.7	7.3	0.3	18.3
	†10.7	7.2	0.4	18.3
Aver.......	10.7	7.3	0.4	
	†10.8	7.5	0.3	18.6
	10.8	8.0	0.1	18.9
Aver.......	10.8	7.8	0.2	
	10.9	7.5	0.2	18.6
	10.9	7.2	0.2	18.3
Aver.......	10.9	7.4	0.2	
	11.0	7.5	0.1	18.6
	†11.0	7.1	0.3	18.4
	†11.0	6.5	0.5	18.0
	†11.0	6.5	0.5	18.0
	†11.0	7.3	0.3	18.6
	11.0	7.9	0	18.9
	11.0	7.4	0.2	18.6
	†11.0	7.2	0.3	18.5
	†11.0	7.2	0.3	18.5
	†11.0	6.7	0.4	18.1
	†11.0	7.0	0.4	18.4
	11.0	7.4	0.2	18.6
	11.0	7.8	0.1	18.9
	11.0	7.6	0.2	18.8
	11.0	7.6	0.1	18.7
Aver.......	11.0	7.2	0.3	

TABLE 8—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	8.1	9.7	0.4	18.2
	8.1	10.0	0.3	18.4
	8.1	10.0	0.3	18.4
	8.1	10.4	0.2	18.7
Aver.......	8.1	10.0	0.3	
	8.0	10.3	0.2	18.5
	8.0	10.3	0.2	18.5
	8.0	10.5	0.2	18.7
	8.0	10.6	0.1	18.7
	8.0	10.8	0.1	18.9
Aver.......	8.0	10.5	0.1	
	7.9	10.1	0.4	18.4
	7.9	11.0	0	18.9
Aver.......	7.9	10.6	0.2	
	7.8	10.2	0.3	18.3
	7.8	10.5	0.2	18.5
	7.8	11.0	0.1	18.9
Aver.......	7.8	10.6	0.2	
	7.7	10.1	0.4	18.2
	7.7	10.6	0.2	18.5
	7.7	11.1	0.1	18.9
Aver.......	7.7	10.6	0.2	
	7.6	11.0	0.2	18.8
	7.6	11.0	0.1	18.7
Aver.......	7.6	11.0	0.2	
	7.5	10.0	0.5	18.1
	7.5	10.8	0.3	18.6
	7.5	10.9	0.2	18.6
	7.5	11.0	0.1	18.6
	7.5	11.1	0.1	18.7
	7.5	11.2	0.2	18.9
	7.5	11.4	0	18.9
Aver.......	7.5	10.9	0.2	
	7.4	11.0	0.2	18.6
	7.4	11.0	0.2	18.6
	7.4	11.4	0.1	18.9
Aver.......	7.4	11.1	0.2	
	7.3	10.7	0.3	18.3
	7.3	11.0	0.3	18.6
	7.3	11.4	0.2	18.9
	7.3	11.5	0.1	18.9
Aver.......	7.3	11.2	0.2	

Six Hour Average Samples

TABLE 7—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	11.1	7.5	0.1	18.7
	†11.1	7.2	0.3	18.6
	†11.1	7.1	0.3	18.5
	11.1	7.7	0.1	18.9
Aver.......	11.1	7.4	0.2	
	11.2	7.5	0.2	18.9
	†11.2	6.8	0.4	18.4
Aver.......	11.2	7.3	0.3	
	11.3	7.0	0.2	18.5
	†11.3	6.7	0.3	18.3
	11.3	7.0	0.2	18.5
	†11.3	6.9	0.3	18.5
Aver.......	11.3	6.9	0.3	
	11.4	7.4	0.1	18.9
	11.4	7.3	0.2	18.9
	11.4	7.1	0.1	18.6
	11.4	7.5	0 0	18.9
	11.4	6.9	0.2	18.5
	11.4	7.1	0.2	18.7
	11.4	7.2	0.1	18.7
	11.4	7.2	0.1	18.7
	11.4	7.1	0.2	18.7
Aver.......	11.4	7.2	0.1	
	†11.5	6.7	0.3	18.5
	11.5	7.2	0.1	18.8
	†11.5	6.5	0.3	18.3
	11.5	7.2	0.1	18.8
	† 11.5	6.6	0.3	18.4
	11.5	7.2	0.1	8.8
	† 11.5	6.3	0.4	18.2
	11.5	7.1	0.2	18.8
	11.5	7.3	0.1	18 9
	11.5	7.3	0.1	18.9
	†11.5	6.2	0.4	18.1
	†11.5	6.0	0.5	18.0
	†11.5	6.1	0.7	18.3
	†11.5	6.2	0.5	18.2
	11.5	7.2	0.1	18.8
	†11.5	6.5	0.3	18.3
	†11.5	6.1	0.5	18.1
	†11.5	6.6	0.3	18.4
	†11.5	6.3	0.5	18.3
Aver.......	11.5	6.7	0.3	
	11.6	7.1	0.1	18.8
	11.6	6.7	0.2	18.5
	†11.6	6.6	0.3	18.5
Aver.......	11.6	6.8	0.2	

TABLE 2—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	7.2	10.7	0.4	18.3
	7.2	10.9	0.2	18.3
	7.2	11.0	0.3	18.5
	7.2	11.0	0.3	18.5
	7.2	11.1	0.2	18.6
	7.2	11.4	0.1	18.7
	7.2	11.4	0.1	18.7
	7.2	11.5	0.1	18.8
	7.2	11.5	0.1	18.8
	7.2	11.5	0.1	18.8
	7.2	11.5	0.1	18.8
Aver.......	7.2	11.2	0.2	
	7.1	11.0	0.3	18.4
	7.1	11.1	0.3	18.5
	7.1	11.4	0.1	18.6
	7.1	11.4	0.2	18.7
	7.1	11.4	0.2	18.7
	7.1	11.5	0.2	18.8
	7.1	11.6	0.1	18.8
Aver.......	7.1	11.3	0.2	
	7.0	11.0	0.4	18.4
	7.0	11.3	0.2	18.5
	7.0	11.3	0.2	18.15
	7.0	11.7	0.1	18.8
	7.0	11.8	0.1	18.9
	7.0	11.8	0.1	18.9
Aver.......	7.0	11.5	0.2	
	6.9	11.3	0.3	18.5
	6.9	11.4	0.2	18.5
	6.9	11.7	0.2	18.8
	6.9	11.8	0.2	18.9
Aver.......	6.9	11.6	0.2	
	6.8	11.2	0.4	18.4
	6.8	12.0	0.1	18.9
Aver.......	6.8	11.6	0.3	
	6.7	11.0	0.4	18.1
	6.7	11.3	0.3	18.3
	6.7	11.5	0.3	18.5
	6.7	11.6	0.2	18.5
	6.7	12.0	0.1	18.8
	6.7	12.0	0.1	18.8
	6.7	12.1	0.1	18.9
Aver........	6.7	11.6	0.2	

SIX HOUR AVERAGE SAMPLES

TABLE 7—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	†11.7	6.0	0.4	18.1
	11.7	6.9	0.2	18.8
	†11.7	6.3	0.3	18.3
	11.7	7.0	0.1	18.8
	†11.7	6.4	0.3	18.4
Aver......	11.7	6.5	0.3	
	11.8	7.0	0.1	18.9
	†11.8	5.4	0.4	17.6
	†11.8	6.2	0.3	18.3
	†11.8	5.9	0.5	18.2
	11.8	6.9	0.2	18.9
	11.8	7.0	0.1	18.9
	†11.8	5.8	0.5	18.1
Aver......	11.8	6.3	0.3	18.
	†11.9	6.2	0 3	18.4
	†11.9	6.1	0.3	18.3
	†11.9	6.0	0.4	18.3
Aver......	11.9	6.1	0.3	
	12.0	6.5	0.2	18.7
	†12.0	5.7	0.4	18.1
	†12.0	5.8	0.4	18.2
	12.0	6.7	0.1	18.8
	12.0	6.3	0.2	18.5
	†12.0	6.3	0.3	18.6
	†12.0	6.1	0.3	18.4
	12.0	6.8	0.1	18.9
	12.0	6.6	0.2	18.8
	12.0	6.6	0.1	18.7
	12.0	6.7	0.1	18.8
	12.0	6.6	0.1	18.7
	†12.0	6.1	0.3	18.4
	†12.0	6.2	0.3	18.5
	12.0	6.4	0.2	18.6
	†12.0	5.8	0.4	18.2
	12.0	6.5	0.2	18.7
Aver......	12.0	6.3	0.2	
	12.1	6.7	0.1	18.9
	†12.1	6.2	0.3	18.6
	12.1	6.4	0.2	18.7
	†12.1	6.1	0.4	18.6
	12.1	6.6	0.1	18.8
	12.1	6.5	0.1	18.7
	†12.1	6.5	0.3	18.9
Aver......	12.1	6.4	0.2	

TABLE 8—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	6.6	11.5	0.3	18.4
	6.6	11.5	0.3	18.4
	6.6	11.6	0.3	18.5
	6.6	12.0	0.2	18.8
	6.6	12.0	0.1	18.7
	6.6	12.0	0.1	18.7
	6.6	12.1	0.1	18.8
Aver.......	6.6	11.8	0.2	
	6.5	11.0	0.5	18.0
	6.5	11.0	0.5	18.0
	6.5	11.5	0.3	18.3
	6.5	11.5	0.3	18.3
	6.5	12.0	0.2	18.7
	6.5	12.0	0.2	18.7
	6.5	12.1	0.1	18.7
	6.5	12.1	0.3	18.9
	6.5	12.2	0.1	18.8
	6.5	12.3	0	18.8
Aver.......	6.5	11.8	0.3	
	6.4	11.7	0.3	18.4
	6.4	12.0	0.2	18.6
	6.4	12.1	0.2	18.7
Aver.......	6.4	11.9	0.2	
	6.3	11.5	0.4	18.2
	6.3	11.5	0.5	18.3
	6.3	11.7	0.3	18.3
	6.3	12.0	0.2	18.5
	6.3	12.0	0.3	18.6
Aver.......	6.3	11.7	0.3	
	6.2	11.5	0.4	18.1
	6.2	11.5	0.5	18.2
	6.2	11.8	0.3	18.3
	6.2	11.9	0.3	18.4
	6.2	12.0	0.3	18.5
	6.2	12.1	0.3	18.6
	6.2	12.2	0.2	18.6
	6.2	12.3	0.2	18.7
	6.2	12.3	0.2	18.7
	6.2	12.3	0.1	18.6
	6.2	12.3	0.2	18.7
	6.2	12.4	0.2	18.8
	6.2	12.6	0.1	18.9
Aver.......	6.2	12.1	0.3	

Six Hour Average Samples

TABLE 7—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	12.2	6.2	0.2	18.6
	12.2	6.5	0.1	18.8
	†12.2	6.1	0.5	18.8
	†12.2	6.1	0.3	18.6
	12.2	5.8	0	18.0
	†12.2	5.6	0.4	18.2
Aver.......	12.2	6.1	0.3	
	†12.3	5.0	0.7	18.0
	†12.3	5.9	0.3	18.5
	12.3	6.0	0.3	18.6
	12.3	6.5	0	18.8
	12.3	6.2	0.2	18.7
	†12.3	6.0	0.3	18.6
	†12.3	5.7	0.3	18.3
	12.3	6.2	0.2	18.7
	12.3	6.2	0.1	18.6
	12.3	6.2	0.2	18.7
Aver.......	12.3	6.0	0.3	
	†12.4	5.2	0.5	18.1
	†12.4	5.5	0.4	18.3
	†12.4	5.5	0.4	18.3
	†12.4	5.4	0.4	18.2
	12.4	6.2	0.2	18.8
	†12.4	5.6	0.3	18.3
Aver.......	12.4	5.6	0.4	
	†12.5	5.1	0.4	18.0
	†12.5	5.0	0.6	18.1
	12.5	6.0	0.2	18.7
	†12.5	5.0	0.7	18.2
Aver.......	12.5	5.3	0.5	
	12.6	6.2	0.1	18.9
	†12.6	5.2	0.4	18.2
	†12.6	5.2	0.4	18.2
	†12.6	6.0	0.3	18.9
	†12.6	5.7	0.3	18.6
Aver.......	12.6	5.7	0.3	
	†12.7	5.1	0.4	18.2
	12.7	5.9	0.1	18.7
	†12.7	5.1	0.4	18.2
	12.7	5.8	0.2	18.7
	†12.7	5.3	0.4	18.4
	12.7	5.7	0.2	18.6
	†12.7	5.3	0.3	18.3
Aver.......	12.7	5.5	0.3	

TABLE 8—Continued

Arranged According to O

	O	CO_2	CO	Total
	6.1	11.5	0.7	18.3
	6.1	11.5	0.5	18.1
	6.1	11.9	0.3	18.3
	6.1	12.0	0.3	18.4
	6.1	12.0	0.3	18 4
	6.1	12.1	0.4	18.6
	6.1	12.2	0.5	18.8
	6.1	12.2	0.3	18.6
	6.1	13.0	0	19.1
	6.1	13.1	0	19.2
	6.1	13.5	0	19.6
Aver.......	6.1	12.3	0.3	
	6.0	11.5	0.5	18.0
	6.0	11.7	0.4	18.1
	6.0	11.9	0.4	18.3
	6.0	12.3	0.3	18.6
	6.0	12.3	0.3	18.6
	6.0	12.5	0.2	18.7
	6.0	12.6	0.3	18.9
	6.0	12.8	0.1	18.9
Aver.....	6.0	12.2	0.3	
	5.9	11.8	0.5	18.2
	5.9	12.3	0.3	18.5
	5.9	12.7	0.1	18.7
Aver.......	5.9	12.3	0.3	
	5.8	11.8	0.5	18.1
	5.8	12.0	0.4	18.2
	5.8	12.0	0.4	18.2
	5.8	12.2	0	18.0
	5.8	12.7	0.2	18.7
	5.8	12.8	0.2	18.8
	5.8	12.9	0.1	18.1
Aver.......	5.8	12.3	0.3	
	5.7	12.0	0.4	18.1
	5.7	12.3	0.3	18.3
	5.7	12.6	0.3	18.6
	5.7	12.7	0.2	18.6
	5.7	12.9	0.2	18.8
Aver.......	5.7	12.5	0.3	
	5.6	12.2	0.4	18.2
	5.6	12.4	0.3	18.3
	5.6	12.8	0.3	18.7
	5.6	12.8	0.3	18.7
	5.6	13.1	0.1	18.8
Aver.......	5.6	12.7	0.3	
	5.5	12.4	0.4	18.3
	5.5	12.4	0.4	18.3
	5.5	13.0	0.3	18 8
Aver.......	5.5	12.6	0.4	

Six Hour Average Samples

TABLE 7—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	†12.8	5.6	0.3	18.7
	†12.8	5.3	0.3	18.4
	12.8	5.8	0.2	18.8
	†12.8	5.1	0.4	18.3
	†12.8	5.4	0.3	18.5
	12.8	6.0	0.1	18.9
	†12.8	5.6	0.3	18.7
	†12.8	4.6	0.6	18.0
Aver.......	12.8	5.4	0.3	
	12.9	5.8	0.1	18.8
	12.9	5.7	0.2	18.8
Aver.......	12.9	5.8	0.2	
	13.0	5.4	0.2	18.6
	†13.0	5.4	0.3	18.7
	†13.0	5.2	0.3	18.5
	†13.0	5.1	0.4	18.5
	†13.0	5.1	0.4	18.5
	†13.0	5.5	0.3	18.8
	13.0	5.4	0.2	18.6
Aver.........	13.0	5.3	0.3	
	13.1	4.9	0.2	18.2
	13.1	5.4	0.1	18.6
	13.1	5.6	0.1	18.8
	†13.1	4.7	0.5	18.3
	†13.1	5.0	0.4	18.5
Aver.........	13.1	5.1	0.2	
	†13.2	4.0	0.8	18.0
	†13.2	5.0	0.3	18.5
	†13.2	4.5	0.5	18.2
Aver.......	13.2	4.5	0.5	
	†13.3	5.0	0.3	18.6
	†13.3	4.7	0.4	18.4
	13.3	5.3	0.2	18.8
	†13.3	4.9	0.3	18.5
Aver.......	13.3	5.0	0.3	
	13.4	5.2	0.1	18.7
	†13.5	4.2	0.4	18.1
	†13.5	4.8	0.3	18.6
	†13.5	4.9	0.3	18.7
Aver.......	13.5	4.6	0.3	
	†13.6	4.2	0.4	18.2
	†13.6	4.6	0.5	18.7
	†13.6	4.6	0.3	18.5
	†13.6	4.6	0.3	18.5
Aver.......	13.6	4.5	0.4	

TABLE 8—Continued

Arranged According to O

	O	CO_2	CO	Total
	5.4	11.8	0.4	17.6
	5.4	12.4	0.4	18.2
	5.4	12.8	0.3	18.5
	5.4	13.0	0.2	18.6
	5.4	13.0	0.3	18.7
	5.4	13.1	0.1	18.6
Aver.......	5.4	12.7	0.3	
	5.3	12.7	0.4	18.4
	5.3	12.7	0.3	18.3
	5.3	12.8	0.3	18.4
	5.3	13.3	0.2	18.8
Aver.......	5.3	12.9	0.3	
	5.2	12.4	0.5	18.1
	5.2	12.6	0.4	18.2
	5.2	12.6	0.4	18.2
	5.2	13.0	0.3	18.5
	5.2	13.4	0.1	18.7
Aver.......	5.2	12.8	0.3	
	5.1	12.5	0.4	18.0
	5.1	12.7	0.4	18.2
	5.1	12.7	0.4	18.2
	5.1	12.8	0.4	18.4
	5.1	13.0	0.4	18.5
	5.1	13.0	0.4	18.5
Aver.......	5.1	12.8	0.4	
	5.0	12.3	0.7	18.0
	5.0	12.5	0.6	18.1
	5.0	12.5	0.7	18.2
	5.0	13.1	0.4	18.5
	5.0	13.2	0.3	18.5
	5.0	13.3	0.3	18.6
Aver.......	5.0	12.8	0.5	
	4.9	13.1	0.2	18.2
	4.9	13.3	0.3	18.5
	4.9	13.5	0.3	18.7
	4.9	13.8	0.1	18.8
	4.9	13.8	0.2	18.9
	4.9	13.9	0.1	18.9
Aver.......	4.9	13.6	0.2	
	4.8	13.5	0.3	18.6
	4.7	13.1	0.5	18.3
	4.7	13.3	0.4	18.4
Aver.......	4.7	13.2	0.5	

SIX HOUR AVERAGE SAMPLES

TABLE 7—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	†13.7	4.3	0.3	18.3
	†13.7	4.3	0.4	18.4
	†13.7	4.3	0.4	18.4
Aver.......	13.7	4.3	0.4	
	13.8	4.9	0.1	18.8
	13.8	4.9	0.2	18.9
	†13.8	4.5	0.3	18.6
Aver.......	13.8	4.7	0.2	
	13.9	4.9	0.1	18.9

TABLE 8—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	4.6	12.8	0.6	18.0
	4.6	13.6	0.5	18.7
	4.6	13.6	0.3	18.5
	4.6	13.6	0.3	18.5
Aver.......	4.6	13.4	0.4	
	4.5	13.2	0.5	18.2
	4.5	13.8	0.3	18.6
Aver.......	4.5	13.5	0.4	
	4.3	13.7	0.4	18.3
	4.3	13.7	0.4	18.4
	4.3	13.7	0.3	18.4
Aver.......	4.3	13.7	0.4	
	4.2	13.5	0.4	18.1
	4.2	13.6	0.4	18.2
Aver.......	4.2	13.6	0.4	
	4.0	13.2	0.8	18.0

ORSAT READINGS

TABLE 9

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	9.8	8.0	0.3	18.1
	10.0	9.9	0	19.9
	10.2	9.7	0	19.9
	11.0	8.3	0	19.3
	11.0	9.0	0	20.0
Aver.......	11.0	8.7	0	19.7
	11.4	8.0	0	19.4
	11.5	6.1	0.3	17.9
	11.6	7.8	0	19.4
	11.8	6.5	0.2	18.5

TABLE 10

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	9.9	10.0	0	19.9
	9.7	10.2	0	19.9
	9.0	11.0	0	20.0
	8.3	11.0	0	19.3
	8.0	11.4	0	19.4
	8.0	9.8	0.3	18.1
Aver.......	8.0	10.6	0.2	18.8
	7.8	11.6	0	19.4
	7.3	12.0	0	19.3
	7.1	12.5	0	19.6

ORSAT READINGS

TABLE 9—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	12.0	7.3	0	19.3
	12.0	7.0	0	19.0
Aver.......	12.0	7.2	0	19.2
	12.3	6.1	0.2	18.6
	12.3	6.7	0	19.0
Aver.......	12.3	6.4	0.1	18.8
	12.5	7.1	0	19.6
	12.7	6.3	0	19.0
	12.8	6.6	0	19.4
	13.0	6.7	0	19.7
	13.0	5.5	0.1	18.6
Aver.......	13.0	6.1	0.1	19.2
	13.2	5.0	0.2	18.4
	13.2	6.2	0	19.4
	13.2	6.8	0	20.0
Aver.......	13.2	6.0	0.1	19.3
	13.4	5.8	0	19.2
	13.5	6.3	0	19.8
	13.5	5.5	0	19.0
	13.5	5.3	0	18.8
	13.5	5.0	0.2	18.7
	13.5	6.2	0	19.7
Aver.......	13.5	5.7	0	19.2
	13.6	5.8	0	19.4
	13.6	4.4	0.3	18.3
	13.6	6.3	0	19.9
Aver.......	13.6	5.5	0.1	19.2
	13.7	6.3	0	20.0
	13.8	6.0	0	19.8
	13.8	6.0	0	19.8
	13.8	6.3	0	20.1
Aver.......	13.8	6.1	0	19.9
	†*14.0	2.1	1.1	17.2
	14.0	4.3	0.2	18.5
	14.0	6.0	0	20.0
	14.0	5.1	0	19.1
Aver.......	14.0	4.4	0.3	18.7
	14.1	5.9	0	20.0
	14.1	5.4	0	19.5
	14.1	4.9	0	19.0
Aver.......	14.1	5.4	0	19.5

TABLE 10—Continued

Arranged According to O

	O	CO_2	CO	Total
	7.0	12.0	0	19.0
	6.8	13.2	0	20.0
	6.7	13.0	0	19.7
	6.7	12.3	0	19.0
Aver.......	6.7	12.7	0	19.4
	6.6	12.8	0	19.4
	6.5	11.8	0.2	18.5
	6.3	13.7	0	20.0
	6.3	12.7	0	19.0
	6.3	13.8	0	20.1
	6.3	13.6	0	19.9
	6.3	13.5	0	19.8
Aver.......	6.3	13.5	0	19.8
	6.2	13.2	0	19.4
	6.2	13.5	0	19.7
Aver.......	6.2	13.4	0	19.6
	6.1	12.3	0.2	18.6
	6.1	11.5	0.3	17.9
Aver.......	6.1	11.9	0.3	18.3
	6.0	13.8	0	19.8
	6.0	14.0	0	20.0
	6.0	13.8	0	19.8
Aver.......	6.0	13.9	0	19.9
	5.9	14.1	0	20.0
	5.8	13.4	0	19.2
	5.8	13.6	0	19.4
Aver.......	5.8	13.5	0	19.3
	5.5	13.0	0.1	18.6
	5.5	13.5	0	19.0
Aver.......	5.5	13.3	0.1	18.8
	5.4	14.1	0	19.5
	5.4	14.4	0	19.8
Aver.......	5.4	14.3	0	19.7
	5.3	13.5	0	18.8
	5.3	14.2	0	19.5
	5.3	14.3	0	19.6
Aver.......	5.3	14.0	0	19.3

Orsat Readings

TABLE 9—Continued

Arranged According to CO_2

	CO_2	O	CO	Total
	†*14.2	2.8	0.7	17.7
	14.2	5.3	0	19.5
Aver.......	14.2	4.1	0.3	18.6
	14.3	5.3	0	19.6
	†*14.3	2.1	0.8	17.2
Aver.......	14.3	3.7	0.4	18.4
	14.4	4.1	0.2	18.7
	14.4	4.2	0.1	18.7
	†*14.4	2.6	0.5	17.5
	14.4	5.4	0	19.8
	†*14.4	3.4	0.5	18.3
	14.4	5.1	0	19.5
Aver.......	14.4	4.1	0.2	18.8
	14.5	5.1	0	19.6
	14.5	5.1	0	19.6
	†*14.5	2.0	0.7	17.2
	14.5	4.3	0.1	18.9
	14.5	2.0	1.0	17.5
Aver.......	14.5	3.7	0.4	18.6
	14.6	2.3	0.9	17.8
	†*14.6	3.0	0.5	18.1
	14.6	2.0	1.0	17.6
	14.6	1.7	0.8	17.1
Aver	14.6	2.3	0.8	17.7
	†*14.7	1.6	0.9	17.2
	†*14.7	2.0	0.6	17.3
	†*14.7	1.6	0.9	17.2
	†*14.7	2.7	0.7	18.1
	14.7	4.0	0.1	18.8
Aver.......	14.7	2.4	0.6	17.7
	†*14.8	2.9	0.5	18.2
	14.8	3.1	0.3	18.2
	†*14.8	1.2	1.1	17.1
	14.8	4.4	0	19.2
	14.8	4.4	0	19.2
Aver.......	14.8	3.2	0.4	18.4
	†*15.0	2.2	0.6	17.8
	†*15.0	2.2	0.5	17.7
	15.0	3.3	0.2	18.5
	15.0	3.0	0.3	18.3

Continued on next page

TABLE 10—Continued

Arranged According to O

	O	CO_2	CO	Total
	5.1	14.4	0	19.5
	5.1	14.5	0	19.6
	5.1	14.0	0	19.1
	5.1	14.5	0	19.6
Aver.......	5.1	14.4	0	19.5
	5.0	13.5	0.2	18.7
	5.0	13.2	0.2	18.4
Aver.......	5.0	13.4	0.2	18.6
	4.9	14.1	0	19.0
	4.7	15.1	0	19.8
	4.4	13.6	0.3	18.3
	4.4	14.8	0	19.2
	4.4	14.8	0	19.2
Aver.......	4.4	14.4	0.1	18.9
	4.3	14.5	0.1	18.9
	4.3	15.5	0	19.8
	4.3	14.0	0.2	18.5
Aver.......	4.3	14.7	0.1	19.1
	4.2	15.3	0	19.5
	4.2	14.4	0.1	18.7
Aver.......	4.2	14.9	0	19.1
	4.1	15.0	0	19.1
	4.1	14.4	0.2	18.7
Aver.......	4.1	14.7	0.1	18.9
	4.0	15.5	0	19.5
	4.0	14.7	0.1	18.8
	4.0	15.5	0	19.5
Aver......	4.0	15.2	0	19.3
	3.8	15.0	0	18.8
	3.8	15.2	0	19.0
Aver.......	3.8	15.1	0	18.9
	3.7	16.3	0	20.0
	3.7	15.8	0	19.5
Aver.......	3.7	16.1	0	19.8
	3.6	15.5	0	19.1
	3.5	16.0	0	19.5
	3.5	16.1	0	19.6
	3.5	15.4	0	18.0
Aver.......	3.5	15.8	0	19.3

ORSAT READINGS

TABLE 9—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
		Continued		
	†*15.0	1.3	0.8	17.1
	15.0	4.1	0	19.1
	†*15.0	1.8	0.9	17.7
	†*15.0	2.2	0.8	18.0
	15.0	3.5	0.2	18.7
	†*15.0	1.8	0.5	17.3
	†*15.0	1.2	0.8	17.0
	†*15.0	2.2	0.5	17.7
	†*15.0	1.8	0.6	17.4
	15.0	3.8	0	18.8
Aver.......	15.0	2.5	0.5	17.9
	15.1	4.7	0	18.9
	†*15.1	2.4	0.5	18.0
	15.1	4.2	0	19.3
	15.1	2.4	0.5	18.0
Aver.......	15.1	3.5	0.3	18.8
	†*15.2	2.1	0.5	17.8
	†*15.2	2.5	0.4	18.1
	15.2	3.8	0	19.0
Aver.......	15.2	2.8	0.3	18.3
	†*15.2	2.4	0.4	18.1
	†*15.3	1.7	0.6	17.6
	†*13.3	1.6	0.5	17.4
	15.3	4.2	0	19.5
Aver.......	15.3	2.5	0.4	18.2
	15.4	3.5	0	18.9
	†*15.4	2.2	0.5	18.1
	15.4	2.9	0.3	18.6
Aver.......	15.4	2.9	0.3	18.5
	15.5	4.0	0	19.5
	15.5	4.3	0	19.8
	15.5	3.0	0.2	18.7
	15.5	4.0	0	19.5
	†*15.5	1.0	0.8	17.3
	15.5	3.6	0	19.1
Aver.....	15.5	3.3	0.2	19.0
	†*15.6	2.1	0.5	18.2
	15.6	2.6	0.3	18.5
	†*15.6	1.9	0.4	17.9
	†*15.6	1.4	0.5	17.5
Aver.......	15.6	2.0	0.4	18.0

TABLE 10—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	3.4	14.4	0.5	18.5
	3.3	15.9	0	19.2
	3.3	15.0	0.2	18.5
Aver.......	3.3	15.5	0.1	18.9
	3.2	16.0	0	19.2
	3.1	16.3	0	19.4
	3.1	14.8	0.3	18.2
Aver.......	3.1	15.6	0.2	18.8
	3.0	15.0	0.3	18.3
	3.0	15.8	0.8	18.8
	3.0	15.5	0.2	18.7
	3.0	14.6	0.5	18.1
Aver.......	3.0	15.2	0.3	18.5
	2.9	15.4	0.3	18.6
	2.9	14.8	0.5	18.2
Aver.......	2.9	15.1	0.4	18.4
	2.8	14.2	0.7	17.7
	2.7	14.7	0.7	18.1
	2.6	15.6	0.3	18.5
	2.6	14.4	0.5	17.5
	2.6	16.5	0	19.1
Aver.......	2.6	15.5	0.3	18.4
	2.5	16.6	0	19.1
	2.5	15.2	0.4	18.1
Aver.......	2.5	15.9	0.2	18.6
	2.4	15.1	0.5	18.0
	2.4	15.1	0.4	18.0
	2.4	15.3	0.4	18.1
Aver.........	2.4	16.2	0.5	18.0
	2.3	15.7	0.3	18.3
	2.3	14.6	0.9	17.8
Aver......	2.3	15.2	0.6	18.1
	2.2	15.0	0.6	17.8
	2.2	15.0	0.8	18.0
	2.2	15.4	0.5	18.1
	2.2	15.0	0.5	17.7
	2.2	15.0	0.5	17.7
Aver.......	2.2	15.1	0.6	17.9
	2.1	15.2	0.5	17.8
	2.1	14.0	1.1	17.2
	2.1	14.3	0.8	17.2
	2.1	15.6	0.5	18.2
Aver.......	2.1	14.8	0.7	17.6

ORSAT READINGS

TABLE 9—Continued

ARRANGED ACCORDING TO CO_2

	CO_2	O	CO	Total
	15.7	2.3	0.3	18.3
	15.7	2.0	0.3	18.0
Aver.......	15.7	2.2	0.3	18.2
	†*15.8	1.0	0.5	17.4
	15.8	3.7	0.6	19.5
	15.8	3.0	0	18.8
Aver.......	15.8	2.6	0.2	18.6
	15.9	3.3	0	19.2
	16.0	3.5	0	19.5
	16.0	3.2	0	19.2
	†*16.0	1.1	0.8	17.9
	†*16.0	1.5	0.4	17.9
Aver.......	16.0	2.3	0.3	18.6
	16.1	3.5	0	19.6
	16.2	2.0	0.2	18.4
	16.3	3.7	0	20.0
	16.3	3.1	0	19.4
Aver.......	16.3	3.4	0	19.7
	16.4	1.3	0.3	18.0
	16.4	1.6	0.2	18.2
Aver.......	16.4	1.5	0.2	18.1
	†*16.5	1.2	0.4	18.1
	16.5	1.8	0.2	18.5
	16.5	2.6	0	19.1
Aver.....	16.5	1.9	0.2	18.6
	16.6	2.5	0	19.1

TABLE 10—Continued

ARRANGED ACCORDING TO O

	O	CO_2	CO	Total
	2.0	16.2	0.2	18.4
	2.0	14.6	1.0	17.6
	2.0	14.7	0.6	17.3
	2.0	14.5	1.0	17.5
	2.0	14.5	0.7	17.2
	2.0	15.7	0.3	18.0
Aver.......	2.0	15.0	0.6	17.7
	1.9	15.6	0.4	17.9
	1.8	15.0	0.5	17.3
	1.8	15.0	0.6	17.4
	1.8	15.0	0.9	17.7
	1.8	16.5	0.2	18.5
Aver..........	1.8	15.4	0.6	17.7
	1.7	15.3	0.6	17.6
	1.7	14.6	0.8	17.1
Aver..........	1.7	15.0	0.7	17.4
	1.6	16.4	0.2	18.2
	1.6	14.7	0.9	17.2
	1.6	15.3	0.5	17.4
	1.6	14.7	0.9	17.2
Aver..........	1.6	15.3	0.6	17.5
	1.5	16.0	0.4	17.9
	1.4	15.6	0.5	17.5
	1.3	15.0	0.8	17.1
	1.3	16.4	0.3	18.0
Aver..........	1.3	15.7	0.6	17.6
	1.2	16.5	0.4	18.1
	1.2	15.0	0.8	17.0
	1.2	14.8	1.1	17.1
Aver..........	1.2	15.4	0.8	17.4
	1.1	16.0	0.8	17.9
	1.0	15.8	0.6	17.4
	1.0	15.5	0.8	17.3
Aver..........	1.0	15.7	0.7	17.4

APPENDIX NO. 2

CALCULATION OF HEAT CARRIED OFF BY THE FLUE GAS

NOTATION

A = weight of air consumed in burning a weight of fuel containing 1 lb. of carbon

A_c = theoretical weight of air required to burn 1 lb. of carbon

A_h = theoretical weight of air required to burn 1 lb. of hydrogen

A_e = weight of air in excess of that theoretically required to burn a weight of fuel containing 1 lb. of carbon

F_c = weight of fixed carbon per lb. of fuel

V_c = weight of volatile combustible per lb. of fuel

$R = \frac{V_c}{F_c}$ = ratio of volatile combustible to fixed carbon in fuel

$R' = \frac{H + C_xH_y}{C}$ = ratio of the volatile combustible to the total carbon in liquid or gaseous fuel

$H_a = H - \frac{O}{8}$ = weight of available hydrogen in fuel per lb. of carbon

O = weight of oxygen in fuel per lb. of carbon

$W_h = O + \frac{O}{8}$ = weight of water of hydration in fuel per lb. of carbon

W_m = weight of water (moisture) in fuel per lb. of carbon

P_a = percentage of moisture contained in air

P = percentage of CO_2 contained in flue gas

P_c = percentage of CO contained in flue gas

P_{vc} = percentage of volatile combustible contained in flue gas, i.e., H and C_xH_y

P_e = percentage of excess of air

L = B.t.u. loss due to sensible heat in flue gas per lb. of carbon in fuel when burned with dry air

L_c = B.t.u. loss due to fuel value of CO in flue gas per lb. of carbon in fuel when burned with dry air

L_{vc} = B.t.u. loss due to fuel value of $(H + C_xH_y)$ in flue gas per lb. of carbon in fuel when burned with dry air

L_v = B.t.u. loss due to moisture in air per lb. of carbon

L_m = B.t.u. loss due to moisture in fuel per lb. of carbon

L_h = B.t.u. loss due to hydrated moisture in fuel

L_t = B.t.u. loss due to all of the above losses per lb. of carbon in fuel burned

T = temperature of flue gas on leaving boiler
t = temperature of air in boiler house
S = specific heat of dry flue gas
S_w = specific heat of water vapor

Pure air contains	by weight	by volume
Oxygen (O_2)	23 %	21 %
Nitrogen (N_2)	77 %	79 %

Weights (lb.) per cu. ft. at 62 deg.fahr.		Specific Heats (S)	
Dry air	0.0761	Air	0.237
N_2	0.0738	N_2	0.244
CO	0.0735	O_2	0.217
CO_2	0.1159	CO_2	0.217
H_2O	0.0472	CO	0.247
		Average	0.23

Specific heat (S_w) of H_2O = 0.48
Atomic weight of H = 1
Atomic weight of C = 12
Atomic weight of O = 16

COMPLETE COMBUSTION WITH THEORETICAL AMOUNT OF AIR

47 One pound of carbon theoretically requires 11.6 lb. or 152 cu. ft. of air for complete combustion, forming 12.6 lb. of combustion product. According to Avogadro's law a molecule of CO_2 occupies the same space as a molecule of O_2, hence the combustion product consists of 21% CO_2 and 79% N_2 by volume. Thus, when burning carbon with its theoretically required volume of air $P = 21\%$, which is the maximum amount obtainable, and the heat carried off by the combustion products will be the minimum, viz: $(A_c + 1) \times (T - t)\, S$. Since $A_c = 11.6$ per lb. of carbon we have

$$L = 12.6\,(T - t)\,S \qquad [1a]$$

Substituting the value of S and reducing ,we have

$$L = 2.9\,(T - t) \qquad [1]$$

COMPLETE COMBUSTION OF CARBON WITH AN EXCESS OF AIR

48 When carbon is burned with an excess of air (A_e), which by volume equals $\frac{A_e}{0.0761}$ cu. ft., then

$$P = \frac{21 \times 152}{152 + \frac{A_e}{0.0761}}$$

from which we get $A_e = \frac{21 \times 11.6}{P} - 11.6$. The total weight of air

$A = A_c + A_e$. Substituting the values of A_c and A_e, we have

$$A = \frac{21 \times 11.6}{P}$$

$$L' = (1 + A) \times (T - t)\, S \qquad \text{[2a]}$$

Substituting the values for A and S and reducing to the lowest terms we have

$$L' = \left(0.23 + \frac{56}{P}\right) \times (T - t) \qquad \text{[2]}$$

The percentage of excess of air for carbon will be

$P_e = \dfrac{A_e \times 100}{A}$. Substituting the values of A and A_e and reducing, we have $P_e = \dfrac{2100}{P} - 100$.

INCOMPLETE COMBUSTION OF CARBON

49 If combustion is incomplete, i.e., if some of the carbon passes off with the combustion product as CO, an additional loss is sustained. Since a pound of carbon burned to CO develops only 4350 B.t.u. instead of 14,500 when burned to CO_2, we have a loss of 14,500 − 4350 = 10,150 B.t.u. for every pound of carbon which passes off as CO.

50 The burning of carbon to CO requires only one-half the weight of air required for CO_2; the presence of CO in the flue gas must, therefore, tend to make the value of A too great; but since P_c is always relatively very small, the presence of CO will not appreciably affect the value of L.

LOSS DUE TO CO IN FLUE GAS

51 When the percentage of CO (P_c) is known, the heat loss due to its presence (L_c) is easily determined. The weight of carbon in a molecule of CO is the same as in a molecule of CO_2 and it follows from Avogadro's law that the weight of carbon burned to CO is to that burned to CO_2 as the per cent of CO is to the per cent of CO_2 contained in the combustion product. Thus, letting X = the weight of carbon burned to CO, we have $\dfrac{X}{1 - X} = \dfrac{P_c}{P}$ from which we get $X = \dfrac{P_c}{P + P_c}$ = carbon burned to CO per unit of carbon contained in the fuel. Since CO burned to CO_2 per unit of carbon develops 10,150 B.t.u., we have $L_c = 10{,}150 \dfrac{P_c}{P + P_c}$. For the total loss when dry carbon is burned with dry air, we have $L_t = L' + L_c$ .... [3a]

Substituting the values of L' and L_c, we have

$$L_t = \left(0.23 + \frac{56}{P}\right) \times (T - t) + 10{,}150\, \frac{P_c}{P + P_c} \qquad \text{[3]}$$

EFFECT OF MOISTURE IN FUEL AND AIR

52 Thus far we have considered both fuel and air to be dry, a condition which never exists in practice. The humidity in the air may vary from a fraction of one per cent to several per cent and commercial fuel is never dry. Coke or charcoal, as well as mineral coal, may contain 10% or more of moisture.

53 Atmospheric moisture exerts a chilling effect on the fire because of its high specific heat and because at least part of it will be decomposed. But since under normal conditions the hydrogen which was set free by decomposition will reunite with the oxygen from the air in the combustion chamber and will evolve as much heat there as was absorbed in the fuel bed in setting it free, there results no heat loss due to this double reaction. It will be necessary, therefore, to consider only the sensible heat carried off by moisture contained in the air, hence

$$L_v = \left(A\frac{P_a}{100}\right) \times (T - t)\, S_v$$

Substituting the values of A and S_v and reducing to lowest terms, we have

$$L_v = \frac{1.17\, P_a}{P} \times (T - t)$$

54 Moisture in fuel (W_m) exists in the form of water which must first be heated to 212 deg. and then evaporated, the vapor passing off at the temperature of the flue gas. Since the latent heat of evaporation is 966 B.t.u. and the specific heat of water vapor is 0.48, we have $L_m = (212 - t + 966)\, M + (T - 212)\, 0.48\, M$. Hence, when burning wet fuel with natural air, we get for the total loss

$$L_t = L' + L_c + L_v + L_m \ldots\ldots\ldots\ldots\ldots\ldots [4a]$$

Substituting values and reducing to lowest terms, we get

$$L_t = \frac{(56 + 1.17\, P_a) \times (T - t)}{P} + \frac{10{,}150\, P_c}{P + P_c}$$

$$+\, 0.23 \times [(T - t) + 110 - t + 48\, T + 966]\, M \ldots\ldots\ldots [4]$$

CALCULATION OF HEAT LOST IN THE FLUE GAS WHEN HYDROGEN FORMS AN APPRECIABLE PART OF THE FUEL

55 In the chemical reaction which constitutes the combustion of hydrogen, 8 lb. of oxygen and 1 lb. of hydrogen unite to form 9 lb. of water vapor. This requires 34.8 lb. or 457 cu. ft. of air and results in 35.78 lb. of combustion product. In commercial flue-gas analysis no account is taken of the moisture, hence nitrogen only is determined in the combustion product from hydrogen. The burning of 1 lb. of hydrogen with the theoretically required volume of air therefore results in 361 cu. ft. of nitrogen.

56 If the fuel consists of carbon and hydrogen and is burned with the theoretically required air, we have $P = \frac{152\ C \times 21}{152\ C + 361\ H_a}$. Placing $C = 1$ and reducing volume to weight, $P = \frac{11.6 \times 21}{11.6 + 26.7\ H_a}$. If there is excess air, we have $P = \frac{11.6 \times 21}{11.6 + 26.7\ H_a + A_e}$, from which we get $A_e = \frac{11.6 \times 21}{P} - 11.6 - 26.7\ H_a$ and $A = A_c + A_h + A_e = \frac{11.6 \times 21}{P} + 8.1\ H_a$. $L'' = (A + 1) \times (T - t)\ S + 9\ H_a\ (T - t)\ S_w$. Substituting for A, A_e, S and S_w their values and reducing to lowest terms we have

$$L'' = (0.23 + \frac{56}{P} + 6.2\ H_a) \times (T - t)$$

57 This formula will give correct results for anhydrous fuel containing hydrogen when burned with dry air, assuming complete combustion. When burning pure carbon fuel (coke or charcoal), CO is the only fuel constituent contained in the combustion product, but as soon as the fuel contains an appreciable amount of volatile combustible, both hydrogen and hydrocarbons may appear in the fuel gas. The loss equation when burning dry hydrocarbon fuel with natural air becomes

$$L_t = L'' + L_v + L_c + L_{vc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots [5a]$$

The last term of this equation will increase in importance with the volatile combustible (V_c) in the fuel. It will be zero with coke and charcoal, insignificant with anthracite, it may approach the value of L_c in bituminous, and will probably equal or even surpass it in liquid and gaseous hydrocarbon fuels.

58 Because of the difficulty encountered in determining the percentage of H and C_xH_y in flue gas, little or nothing is known as to their quantitive relation to CO_2 and CO. It may be assumed, however, with a considerable degree of certainty that if a fuel is burned to such a degree of completeness that no measurable amount of CO is found in the flue gas, H and C_xH_y will also be absent. It would even seem probable, and therefore reasonable to assume, at least until the contrary has been demonstrated, that in the combustion of any hydrocarbon fuel the absence of CO may be considered as evidence of complete combustion. But when CO is present in the flue gas from hydrocarbon fuel, H and C_xH_y constitutents must also be suspected and should be included in any formula which pretends to express the total loss of heat and fuel through the chimney, even though it is not practicable to determine these constituents in the daily flue-gas analyses.

59 It is reasonable to suppose that the tendency for H and C_xH_y to be associated with CO when combustion is incomplete will increase with the volatile combustible (V_c) contained in the fuel. We may, therefore, assume that the percentage of H and C_xH_y in the flue gas is to the CO as the percentage of volatile combustible in the coal is to the fixed carbon. Representing the latter ratio by R, we have $R = \frac{P_{vc}}{P_c}$, from which we get $P_{vc} = P_c R$.

60 For liquid and gaseous fuels containing little or no fixed carbon we will probably not be far wrong if we assume this ratio to be equal to the ratio of the hydrogen and hydrocarbon combustibles to the total carbon content of the fuel, i.e.,

$$R' = \frac{H + C_xH_y}{C} = \frac{P_{vc}}{P_c}. \text{ Hence } P_{vc} = P_c\mathrm{R}'$$

61 Then if we let the heat value of the hydrogen and hydrocarbon combustibles in the flue gas equal that of CO, volume for volume, we have $L_{vc} = 10{,}150\,P_cR$.

$$L_t = L'' + L_v + L_c + L_{vc} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5a]$$

Substituting the values previously determined and reducing to lowest terms, we have

$$L_t = \frac{(56 + 1.17\ P_a) \times (T - t)}{P} + \frac{10{,}150\ (P_c + P_cR')}{P + P_c}$$
$$+ (0.23 + 6\,H_a) \times (T - t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots [5]$$

62 There is no experimental data at hand to prove or disprove the substantial correctness of the above relation. All that can be said in its favor is that it would appear reasonable that such relation exists between the CO and the other combustible constituents contained in flue gas. Equation [5] represents the total heat loss up the stack when burning liquid or gaseous fuel free from moisture.

WATER OF HYDRATION

63 All mineral coals contain water in two forms: moisture (W_m), i.e., water which can be driven off by drying at about 212 deg.; and water of hydration (W_h), which passes off at much higher temperatures with the volatile combustible matter, the estimation of which is ordinarily but wrongly included in the latter. True moisture (W_m) has already been considered.

64 If we know the weight of oxygen contained in the coal, the water of hydration is determined by the equation $W_h = O + \frac{O}{8}$, i.e., 1 lb. of oxygen combines with $\frac{1}{8}$ lb. of hydrogen and forms $\frac{9}{8}$ lb. of water. We therefore have $L_h = 1.125 \times O \times (T - t)\,S_v = 0.54 \times O \times (T - t)$. The total sensible and potential heat carried off by the flue gas from bituminous coal therefore becomes

$$L_t = L'' + L_v + L_c + L_{vc} + L_m + L_h \ldots\ldots\ldots\ldots [6a]$$

Substituting and arranging terms, we have

$$L_t = \frac{(56 + 1.17\ P_a) \times (T - t)}{P} + \frac{10{,}150\ (P_c + P_cR)}{P + P_c} + (0.23 + 0.54 \times O)$$
$$\times (T - t) + (110t + 0.48T + 966)\ M + 0.23 \ldots\ldots\ldots [6]$$

From these heat loss equations we see that the loss of heat by way of the chimney is the sum of a number of distinct components; and that the loss occurs in two ways, (*a*) sensible heat and (*b*) unconsumed combustible.

65 When burning carbon fuel the loss components are

$$L_t = L + L_c + L_v + L_m \ldots\ldots\ldots\ldots\ldots\ldots\ldots [4a]$$

The values of thsee components are

$$L' = (0.23 + \frac{56}{P} \times (T - t)$$

$$L_v = \frac{1.17\ P_a}{P} \times (T - t)$$

$$L_c = \frac{10{,}150\ P_c}{P + P_c}$$

$$L_m = (110 - t + 0.48\ T + 966)\ M$$

When burning mineral coal the loss components are

$$L_t = L' + L_v + L_c + L_{vc} + L_m + L_h \quad \text{[6}a\text{]}$$

The values of these components are

$$L'' = (0.23 + \frac{56}{P} + 6.2\ H_a\ ) \times (T - t)$$

$$L_v = \frac{1.17\ P_a}{P} \times (T - t)$$

$$L_c = 10{,}150 - \frac{P_c}{P + P_c}$$

$$L_{vc} = 10{,}150\ \frac{P_c R}{P + P_c}$$

$$L_m = (110 - t + 0.48\ T + 966)\ M$$

$$L_h = 0.54 \times O \times (T - t)$$

66 From the values of the components of equation [4*a*] we see that the loss due to the first three decreases directly as the CO_2 increases and the loss due to the first, second and fourth increases directly with the temperature of the escaping flue gases. Similarly, we see from the values of the components of equation [6*a*] that the loss decreases as the CO_2 increases in the first four components, and increases with the flue-gas temperature in the first, second, fifth and sixth.

NOTES ON A HEAVY-DUTY GAS PRODUCER

By Nisbet Latta, Milwaukee, Wis.
Junior Member

The heavy-duty gas engine may be said to have been developed in the United States to a reasonable degree of commercial acceptability. The adoption of this engine by the various steel companies, the economical operation of the engines installed and the general degree of reliability obtained has established it upon a firm foundation as a recognized prime mover in this industry. The general adoption of the gas engine, however, and its refinement, with regard to those obstacles which yet remain and which can only be eliminated through a prolonged process of evolution, must depend upon a wider field. Such expansion of field depends upon a supply of fuel suitable in uniformity and economy for use in the internal combustion engine.

2 Generally speaking, the heavy-duty gas engine has been confined to those operations where either natural gas or blast-furnace gas was available; hence, before they can be generally adopted, some method for the economical manufacture of a satisfactory gas in large volumes must be assured. The difficulties of such manufacture have been many, and a few of them are herewith recited.

3 The initial introduction of gas producers into the United States was unfortunate and the failure of the greater number of the first installations cast upon the producer a cloud of discredit which has never been removed entirely from the public mind. This failure was due, in most part, to the wrong hypothysis that because this apparatus has been successful in England and on the Continent it must necessarily be so in this country. The fallacy of this idea was due to the single variable, the nature of the fuel used. The easily fusible ash contained in the English and German coals permitted a high rate of combustion, averaging 18 lb. to 20 lb. per sq. ft. of cross section. When operation at this rate was attempted here, it was found to be impossible to control the fire bed, the resulting temperature being such as to

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flux and finally fuse the ash and to produce other conditions inconsistent with satisfactory operation.

4 To avoid this condition of affairs, the rating of American producers has steadily been decreased until the best practice now averages from 8 lb. to 9 lb. of fuel gasified per square foot of grate surface. This change has rectified to a great extent the difficulties met with in the introduction of the apparatus upon this side of the Atlantic. The success of such installations as the Tait process at the John Thompson Press Company and the Loomis-Pettibone plant of the Milwaukee Northern Railway Company are examples of the development of the American producers properly engineered. Such plants, however, are relatively small in size, while the heavy-duty gas engine for power purposes is essentially an apparatus of large capacity and demand. The average gas producer in common practice today does not exceed 500 h.p. in size.

5 Even at this size, and invariably beyond it, mechanical troubles occur which are difficult if not impossible to remedy. For instance in producers of great diameter there are different heat zones or strata, due to the difference of temperature between the center of the apparatus and the sides, which are cooled to some extent by radiation. Moreover, the increase in diameter causes almost insurmountable difficulties in stoking and prevents the possibility of maintaining the fuel bed at a high efficiency.

6 Again, the labor of cleaning is immeasurably increased. This condition of affairs is peculiarly emphasized in the case of caking or coking coals containing a high percentage of fines (coal under ¼-in. mesh) which tend to form a homogeneous mass, packing or caking the bed. Coals such as are found in Kansas or Illinois, particularly the former, make operation difficult under these conditions. The commercial limit of fines in the case of pressure producers seems to be about 15 per cent for caking coal and about 40 per cent for free-burning coal. With the latter 65 per cent of fines is the maximum obtained in commercial operation. In some coals the ash fuses at an early stage of combustion, while others form a densely packed or "mucky" bed, almost like molten asphalt.

7 The difficulty and labor of operation under these conditions has hitherto been met by some expedient such as mechanical agitation. The well-known Hughes producer, an instance of this type, has a "walking-beam" poker which periodically punctures and stirs the fuel bed. Other mechanical methods have involved the rotation of

one or more zones of the producer so as to turn or twist separate sections of the fire bed upon its own axis. Sections of the producer have also been caused to oscillate and such arrangements as shaking or rotative grates have been long and commonly used. Another method of agitation, perhaps more unique, is in successful practice in certain types of the Loomis-Pettibone apparatus, wherein compressed gas is used as the agitating medium. A certain volume of gas is compressed into a small storage tank or receiver, from which a gas-opening valve suddenly admits it under the fuel bed of the producer, the result being to lift the bed and redispose it, to blow out the ashes from the interstices of the fuel, and to refresh and make more active the fuel surface. This method, especially within a producer of moderate size, can unquestionably be commended.

8 Nevertheless, the fact remains that although the medium-sized producer, of say 750 h.p., has been developed with a reasonable degree of commercial success, we have not as yet obtained a gas-producing apparatus which may be said to be a consort for the heavy-duty steel-plant type gas engine of 3000 to 5000 horsepower.

9 The argument has been presented that the solution of the matter consists in the use of a number of producer units and their connection in batteries or multiples, analogy being made with steam boiler practice. The installation of a 2000-h.p. steam turbine would not necessitate the construction of a 2000-h.p. steam boiler, but more likely four 500-h.p. units or even three 750-h.p. units, allowing a safe factor for easy steaming. This analogy fails by reason of the essential difference in the character of the service performed. For instance, within certain limits the question of boiler operation means merely the delivery of steam at a certain pressure, the pressure regulation between the boilers being a matter which is comparatively simple. The efficient operation of a gas engine, however necessitates the delivery not only of a continuous supply of gas, but gas of uniform composition. This condition of affairs is made even more complex where the load is variable, and the process of synchronizing and maintaining in synchronism the multiplicity of producer units is more difficult in practice than it would seem theoretically. Again, there are inherent industrial disadvantages such as relatively high labor costs, increased cost of maintenance, and complex coal and ash-handling devices.

10 The foregoing summary will briefly explain the reason for starting about a year ago, a series of experiments on a large-sized mechanically-operated producer. Although incomplete as yet, they

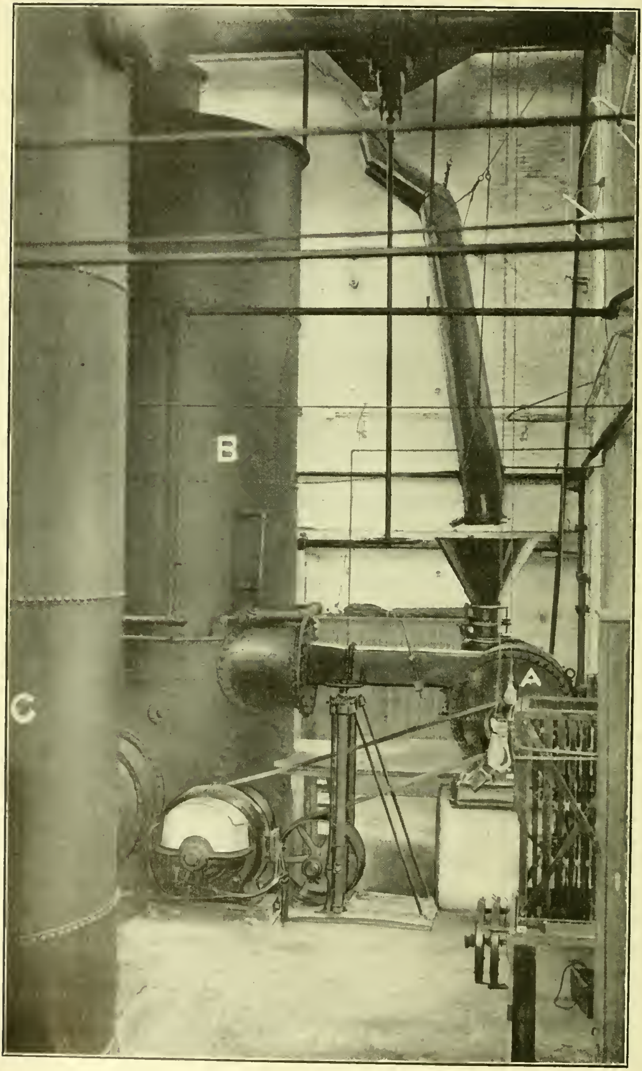

Fig. 1 3000 H.P. Hirt Producer and Equipment

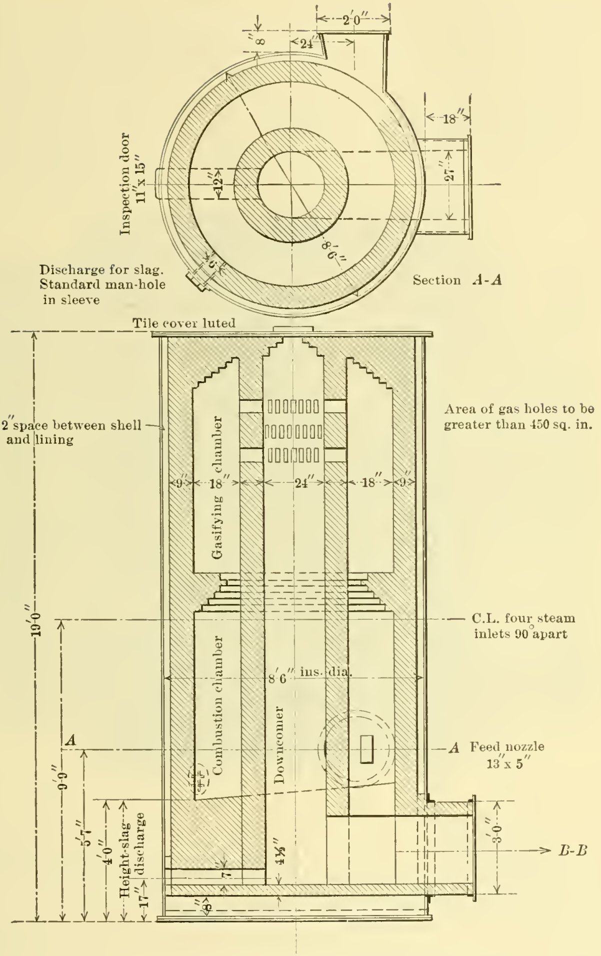

Fig. 2 Vertical Section of Hirt-Producer

tend to show the possibilities of the manufacture of gas on a large scale at a low cost.

11 The apparatus selected was of the pulverized-fuel type, the one herein described having originally been designed by L. H. Hirt. This type of producer is hardly an innovation, having been in operaton in France for a number of years. The French producer was the work of Georges Marconnet, a French engineer. This apparatus is used to supply gas fuel to engines for the generation of power and to open hearth furnaces, being known as the Marconnet Gasogene.

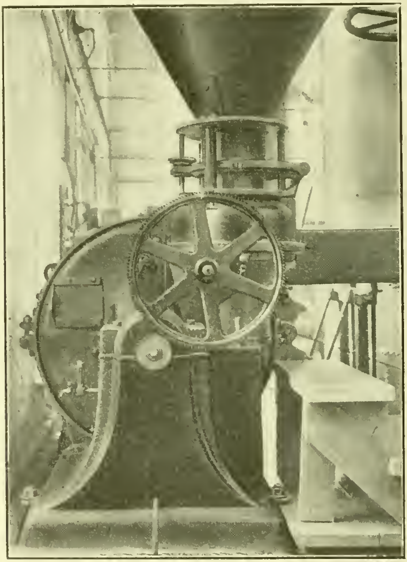

Fig. 3 Fuel Pulverizer and Mixing Machine

12 The Hirt Apparatus (Fig. 1) consists of a pulverizer, *A*, a retort or furnace, *B*, a tower scrubber or other cleaning device, *C*. The fuel is broken to a reasonable uniform size of say $\frac{3}{4}$ in. by its passage through a crusher or griffin mill, from which it usually passes through a storage hopper to the pulverizer. Here it is ground to a satisfactory degree of fineness in the presence of air. Not only is a high degree

of intimacy on the part of the elements secured, but by this arrangement coal containing a maximum of 12 per cent to 15 per cent of moisture may be ground without pre-drying. The mixture lacking sufficient air to permit complete combustion, is then admitted tangentially into the producer or retort through opening *B* (Fig. 3). After combustion, the gas takes an upward course through the gasifying chamber and passes down the central passage, escaping at *BB* into the scrubber.

13 Heretofore the difficulty experienced in operation with pulverized fuel has been caused largely by the high heat of combustion and the impossibility of maintaining a refractory material under such conditions of intense temperature. It must be noted, however, that in the operation of this producer the combustion is incomplete. In starting up the producer it is necessary to permit complete combustion for a sufficient period to raise the linings to the heat of gasification, this temperature being subsequently maintained by the reaction of gasification in the natural process of manufacture within the apparatus. According to Alexander M. Gow,[1] 4450 B.t.u. are liberated

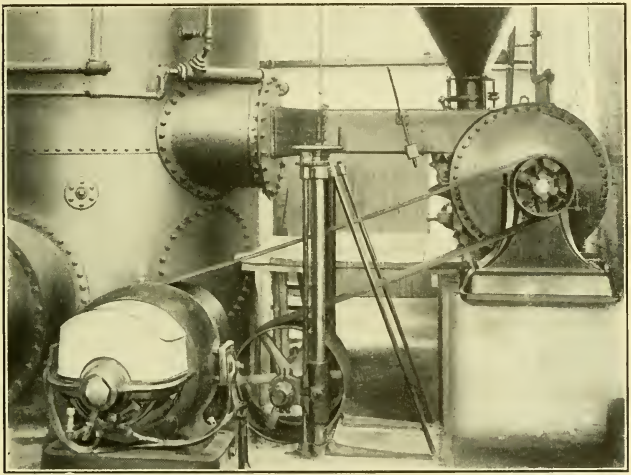

Fig. 4 Pulverizer and Producer Connections

when a pound of carbon is burned or oxidized to CO. Assuming that the function of this producer is to oxidize carbon to CO, and inasmuch as the weight of the entire products of combustion of one pound of carbon burned to CO is 6.76 lb.,[2] by substituting these values in the formula $t = \frac{(B.t.u.)}{W X Z}$ and taking an average specific heat for the products of combustion, the theoretical temperature derived would be practically 2240 deg. fahr. The oxidation of carbon[3] begins at the

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[1] Trans. Engineers' Society of Western Pennsylvania, May 1903, p. 14.

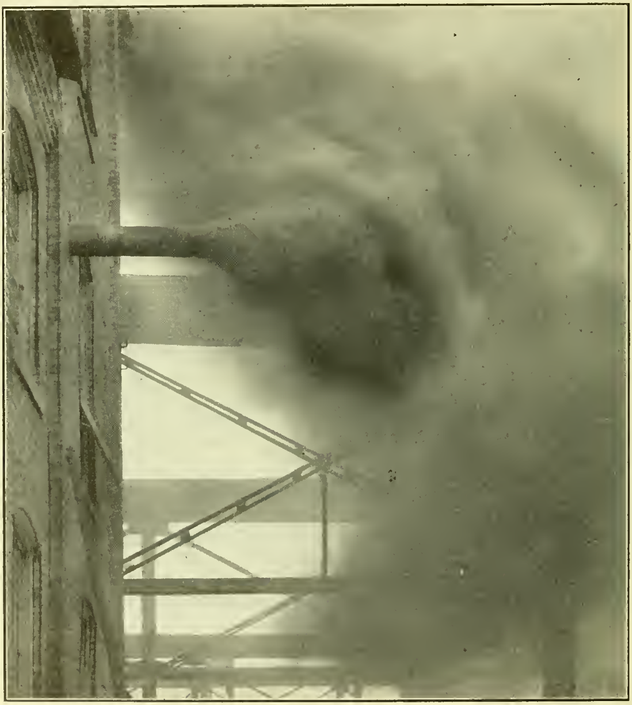

FIG. 5 3000 H.P. IN GREEN GAS DISCHARGED FROM PRODUCER THROUGH 12-IN. OUTLET low temperature of 400 deg. cent. (752 deg. fahr.), the reaction being complete at 995 deg. cent. (1823 deg. fahr.). These facts merely serve to indicate that the exothermic reaction $2\ C + O_2 = 2\ CO$ would be sufficient to supply all heat necessary for the operation of the producer.

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[2] Ingalls, Metallurgy of Zinc and Cadmium, p. 264.

[3] Ingalls, Metallurgy of Zinc and Cadmium, p. 280.

TABLE 1 ANALYSES OF PRODUCER GAS

Carbon Monoxide, %	23.7	27.5	26.5	27.0	24.5	15.85	13 52	12.20	18 2	13.8	18.9
Carbon Dioxide, %	3.9	2 8	2 9	5.0	3 9	9 20	8 10	7.60	4 9	8 0	9 4
Hydrogen, %	10.0	11.5	11 0	9.5	9.8	6.17	11 51	10.50	12.2	10 4	12.2
Methane, %					3.4	4.09	5.17	3.20	2.1	2.5	.....
Oxygen, %						1.40	0 30	0	0.1	0	. . .
Nitrogen, %						63.29	61 40	66 50	62 4	64 8	.....
Illuminants, %							....	......	0 1	0.5	.....
B.t.u. per Cu. Ft., Total							...	......	128 89	119 70	.....

* Steam admitted to upper chamber.

TABLE 2 PROXIMATE ANALYSES OF COAL

Moisture, %	0.52	1.20*	0 73
Vooatile Matter, %	17.50	32.95	17.52
Fixed Carbon, %	72 48	59.64	76 80
Ash, %	9.50	6 21	4.95
Sulphur, %	1 24	......	......
B.t.u. (dried)	......	13.925	14.550

*Analysis of ash from above coal: silica, 43,62; aluminum and iron oxide, 42.00; lime, 5.74; magnesia, 2.22.

14 Perhaps the only serious difficulty met with in the continuous and uniform operation of the apparatus was caused by the construction of the producer upon the hypothesis of the inventor that all coals could be carried up at a temperature at which the ash would fuse, so that it could be removed in the form of slag. This was an error which soon developed. It has been demonstrated that only fuels containing easily fusible ash can be handled in such a manner, and that these fuels are the exception, rather than the rule. The apparatus having been constructed upon this premise, the removal of ash was a clumsy and inconvenient performance. It was necessary to accumulate an ash bed sufficiently deep to seal the producer and then gradually and carefully withdraw it from the bottom. This difficulty, however, would be easily remedied in a producer designed with the knowledge of the foregoing experiments. Either a water-sealed bottom or a conical dumping bottom would be entirely convenient and economical of operation.

15 In the experiments herein cited the pulverizer was driven by an electric motor. In commercial operation, however, the sensible heat of the effluent gases would be more than sufficient to generate steam to drive all auxiliary apparatus and even to supply a surplus for any useful purpose. The interposition of a waste-heat boiler between the producer and the scrubber, such as is used in the Loomis-Pettibone apparatus or in connection with water-gas sets would unquestionably act with entire satisfaction.

16 Bituminous coals of a wide range were used and the operation of the producer upon fuels containing up to 30 per cent of ash and 15 per cent of moisture was commercially demonstrated. Some typical analyses of the gases, as made by the Pittsburgh Testing Laboratories are given in Table 1.

17 There is, however, a definite ratio existing between the fuel used, the degree of fineness to which it is ground and the time the gas remains within the producer. That is, adjustment should be made to suit the chemical analysis and the physical nature of the given fuel. The length of the downcomer should depend upon both of these elements, the length varying, in all probability, inversely as the percentage of volatile matter contained in the coal.

18 The success of these experiments and the field of development opened up thereby will undoubtedly have a powerful impetus to the development of large gas-generating units, for the results obtained, as reflected in the analyses of the gas, show a very high efficiency for the apparatus and a remarkable uniformity in its product. Considered as a whole, it presents at least one available source of gas supply for the heavy-duty gas engine.

TEST OF A 10,000-KW. STEAM TURBINE

WITH A BRIEF DESCRIPTION OF FEATURES OF CONSTRUCTION

By Sam. L. Naphtaly, San Francisco, Cal.

Member of the Society

The steam turbine has experienced, as is quite universally known, the most rapid development of any form of prime mover, and its application has been extensively broadened within the last few years. Recent proceedings of this Society contain, in the paper on small steam turbines by Geo. A. Orrok and on tests of a 15,000-kw. engine-turbine unit by Messrs. Stott and Pigott, useful data on small units and low-pressure turbine operation, respectively.

2 It is the intent of this contribution to record the attainment in the design and operation of a complete-expansion turbine of 10,000-kw. normal rating, installed in the latter part of 1909 in the main power station of the City Electric Company, San Francisco, Cal., under the author's management, and recently tested under the direction of J. G. White and Company, consulting engineers.

3 The object of the test was to determine the general steam consumption of the turbine unit under everyday operating conditions and further to determine whether the builder's guarantees of economy, generator, temperature, etc., had been complied with.

4 The contract with the builder specified a turbine of 10,000-kw. normal capacity with an additional overload capacity of 50 per cent operating with steam at 175 lb. gage pressure, superheated 100 deg. fahr. and with 28-in. vacuum, measured in the exhaust pipe and referred to a 30-in. barometer. Under the above conditions, operating at 1800 r.p.m., the guaranteed performance was as follows:

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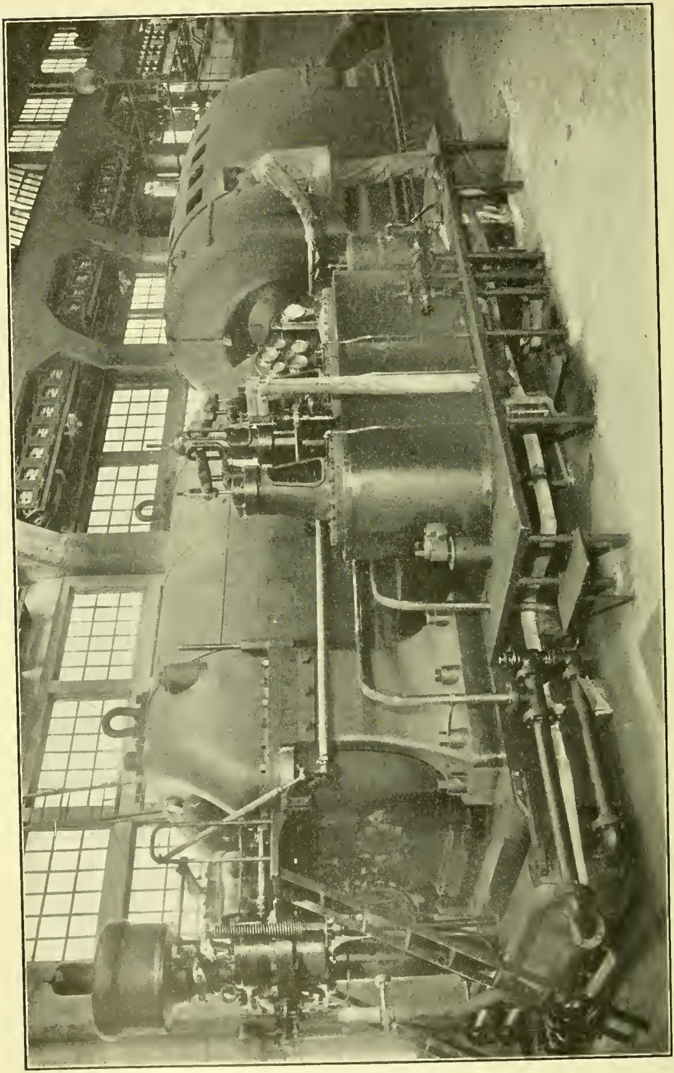

FIG. 1 GENERAL VIEW OF TURBO-GENERATOR

Full load	10,000 kw.	14.3 lb. per kw-hr.
½ load	5,000 kw.	16.2 lb. per kw-hr.
1½ load	15,000 kw.	15.3 lb. per kw-hr.

5 The generator was designed for a 60-cycle, 3-phase current, its normal rating being 525 amperes per terminal at 11,000 volts, the voltage maintained constant at all loads by means of a Tirrill regulator. The generator is of the enclosed type and is provided with a direct-connected exciter, driven from the end of the main generator shaft.

6 The generator was specified to have a temperature rise in any part above the temperature of the ingoing cooling air, not exceeding the following:

Full-load current, normal voltage, for 24 hr., 40 deg. cent.
1¼-load current, normal voltage, for 24 hr., 50 deg. cent.
1½-load current, normal voltage, for 24 hr., 60 deg. cent.

7 The steam turbine is of the double-flow type, containing both impulse and reaction elements. The exterior of the unit, as installed in the power plant is shown in Fig. 1, while Fig. 2 shows a longitudinal section of the turbine.

8 Certain features of construction of the turbine are as follows:

a Double-flow design, employing a single high-pressure impulse wheel centrally located. A division of steam between two similar and opposed intermediate and low-pressure reaction elements, one-half flowing through the annulus surrounding the high-pressure wheel, shown by arrows in Fig. 2. The large capacity and high rotative speed of the unit make it possible to utilize the double-flow construction, which has many obviously desirable features. Indeed it may be said that for this capacity and rotative speed, the double-flow construction is imperative, since in a single-flow machine of the same capacity and speed the blade lengths in the low-pressure section will be so great as to preclude the possibility of sound mechanical construction or efficient steam distribution.

b Symmetry of cylinder structure resulting from the double-flow design, favors the production of the casting with least initial strain, and permits of uniform distribution of temperature strains.

c High speed reduces the metal masses, ensuring greater homogeneity of casting with a resulting increased factor

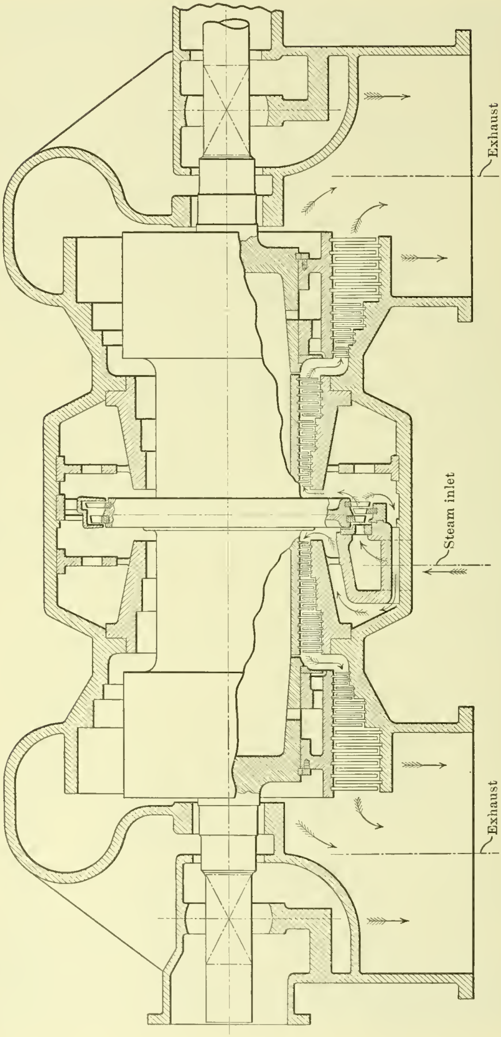

Fig. 2 Sectional View of Turbine

of safety, since the same peripheral speeds and centrifugal stresses virtually obtain as in the lower rotative speed designs.

d Turbine cylinder simplified with intermediate stationary element cast separately and hence subject to less internal strains. Provision is made for the ready removal of these parts.

e There are no feet cast on the cylinder for supporting it on the bedplate. Instead, there are provided cast-iron chairs, two at each end, as seen in Fig. 1. The cylinder is carried by these chairs in a horizontal plane close to the axis of the turbine, the advantage being that with this construction the alignment of the coupling is less affected by temperature changes. The cylinder is free to slide on these chairs permitting unrestrained expansion of the parts. In fact the turbine is not secured at any point except where it joins the generator inboard bearing pedestal which, however, is rigidly bolted to the plate.

f The governing apparatus, while containing many improvements in detail, presents no particularly novel features. There are two governor-controlled inlet valves, each admitting steam to a group of nozzles; full load being carried on the primary valve alone. Overloads are maintained by a group of nozzles operated by the secondary valve.

9 These main valves and their operating mechanism are shown in detail in Fig. 3. They are hydraulically operated, oil under pressure being supplied by the oil pump driven by the turbine. The entire output of this pump is not necessarily used by the governor, the surplus escaping through a spring-loaded valve, which together with that discharged from the valve-operating mechanism, furnishes the oil supply for the bearings. The operation of the hydraulic gear is, as is seen from Fig. 3, accomplished by the familiar relay and floating lever. Hitherto, it has been customary to construct the relay for a mechanism of this character without lap. If it does have lap, either negative or positive, the amount of this lap must be traveled before the mechanism can respond to the governor. A departure is here made from previous practice in providing the relay plunger with both inside and outside laps. The relay is kept oscillating a small amount by means of a cam connected to the governor linkage, sufficiently to uncover slightly the ports at each oscillation, causing a correspond-

ingly slight motion of the main operating piston. The effect of the governor itself on this relay, is, of course, to change its plane of motion, and hence response to the least change in position of the governor weights is thus assured.

10 The condenser is of the Wheeler-surface dry-tube type, equipped with primary feed heaters, turbine-driven centrifugal hotwell pump, and rotative dry vacuum pump. The condenser is located immediately below the turbine and is provided with two openings connecting with the exhaust at each end of the turbine. It contains 25,000 sq. ft. of 1-in. tube, No. 18 gage. A 42-in. cast-iron conduit, located so as to be submerged even at extreme low tide, conducts salt water direct from the bay of San Francisco to the plant. After being pumped through the condensers the salt water is returned to the bay through a suitable channel.

11 The turbine generator is of the builder's most recent four-pole construction. The field is of nickel steel and is made up of two halves joined end to end by shrink links. Each half is integral with its shaft, which renders any hole for the shaft unnecessary and consequently considerably increases the strength of the revolving field. The field winding is done under heavy tension, which results in a very solid mechanical construction. The rotor is provided with a series of turbine fan blades, and the ends of the armature winding are covered by stationary end bells which, in addition to protecting the winding serve as means of conducting the cooling air from the air ducts to the machine. This air is drawn from the conduits by means of the turbine blowers through the armature winding and is forced into the air gap, whence it passes outward through the armature laminations and is discharged into an exhaust air duct.

12 As this was the first generator of this design constructed, the City Electric Company insisted that tests be carried out by the builders before shipment, which showed an electrical efficiency at $\frac{1}{4}$ load of 92.2 per cent; at full load of 97.6 per cent and at $1\frac{1}{2}$ load of 98.2 per cent.

13 From the compromise tests which it was possible to make in the works, it was figured that the temperature rises at full load, 100 per cent power factor, would be 28 deg. on the armature laminations and 18 deg. on the field, by thermometer, the temperature rises by resistance being 22 deg. on the armature winding and 35 deg. on the field winding.

14 The tests by J. G. White and Company confirm these figures, their results showing that on a load of 5300 kw. at 89 per cent power

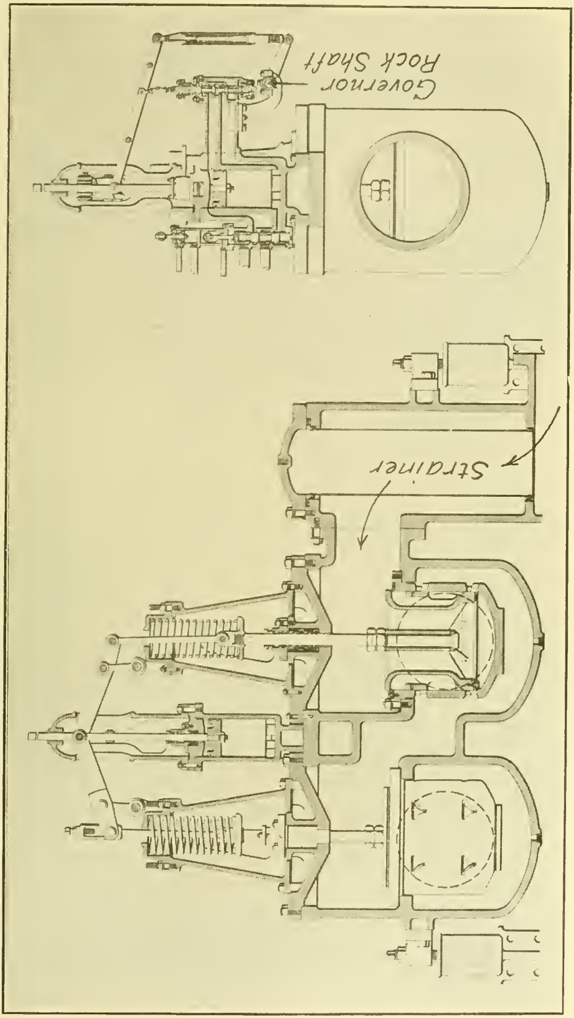

FIG. 3 GOVERNOR OPERATING MECHANISM

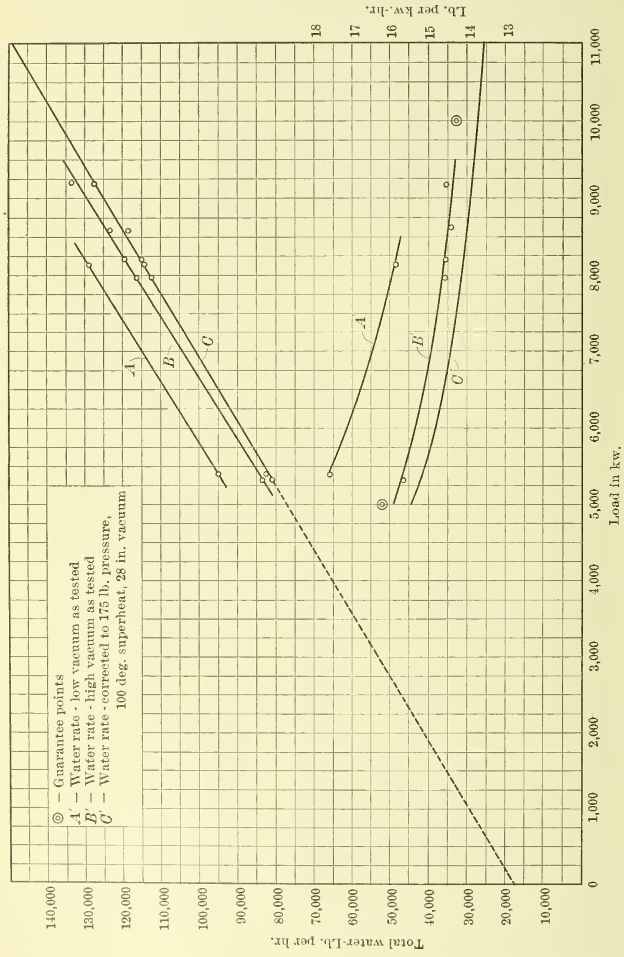

Fig. 4 Actual Water-Rate Curves Obtained from Tests

factor, that is, 6000 k.v.a., the maximum temperature rise of the armature was constant at 27 deg. On a load of 9300 kw., 89 per cent power factor, that is, 10,400 k.v.a., the maximum temperature rise was constant at 31 deg. These figures are well within the guarantees.

DETAILS OF TURBINE TEST

15 In what follows details are given of the turbine test made after installation, the results being shown by the curves, Fig. 4 and Table 1. It is unfortunate that the unit had to be maintained carrying the station load during the tests. During the high-load tests, it was the only unit operating in the station, so that observations had to be made under these conditions, with the load variations incidental to station operation. In all, seven runs were made, two of which, *E* and *G*, were at low vacuum for the purpose of establishing the effect of variations of vacuum on this machine. In Table 1, both the Rankine cycle and thermal efficiencies have been given in addition to the rate of steam consumption in pounds per kilowatt-hour, which is the usual method of stating the performance of the steam motor. The thermal efficiency considers only the heat in the steam from the boiler, and is of use only for comparing results with other forms of prime movers, such as internal combustion engines. The Rankine cycle efficiency, or efficiency ratio as it is sometimes called, is the more equitable measure for comparison of steam motors, as it reckons with the work done

TABLE 1 SUMMARY OF TEST OF 10,000-KW. TURBINE

CITY ELECTRIC CO., SAN FRANCISCO, MARCH 1910

Run	Date 1910	Duration. hours	Actual Load, kw.	P. F., per cent	Steam Pressure, lb. Gage	Superheat, Deg. Fahr.	Vacuum 30-in. Bar.	Water per hour, Total, Lb.	Water per kw-hr. as Tested	B.t.u. per kw-hr.	Rankine Cycle Eff. as Tested	Thermal Eff., Per Cent	Lb. per kw-hr. Corrected 175 lb. 100 Deg. Sup. 28-in. Vac.	Remarks
A	3-14	1.5	7972	90	171	58	28.28	116238	14.581	15378	66.9	22.20	14.11	High Vacuum
B	3-14	2.0	8563	88	168	59	28.18	123542	14.427	15062	68.0	22.65	13.88	High Vacuum
C	3-14	2.0	8198	91	169	60	28.10	119655	14.596	15414	67.6	22.10	14.04	High Vacuum
D	3-14	2.0	9173	91	167	59	27.90	133672	14.572	15360	69.0	22.23	13.88	High Vacuum
E	3-15	3.0	5333	88	173	54	28.34	83478	15.655	16493	61.8	20.70	15.21	High Vacuum
F	3-15	4.0	8148	88	167	60	26.16	129181	15.855	16782	69.5	20.35	14.07	Low Vacuum
G	3-16	3.0	5401	88	174	56	26.16	95120	17.611	18587	62.2	18.35	15.24	Low Vacuum

Note: The above summary of the entire test varies but ¼ of one per cent from the average of the 15 minute readings taken during the test.

between the limits of steam leaving the boiler and exhaust entering the condenser. Taking the heaviest load carried, run *D*, the efficiency ratio obtained was 69 per cent including generator and field losses which, I believe, is some improvement over results hitherto obtained for a complete-expansion turbine.

16 The performance of a steam turbine follows the Willans right-line law over a great range of its capacity, which gives a valuable check on the accuracy of the test points and reduces the number of necessary runs to a minimum. Furthermore, the performance of a turbine may be accurately predicted at loads beyond the range at which tests have been run. Referring to Fig. 4, it is reasonable to expect that if a higher load had been available, the steam consumption would have further improved until the opening of the secondary valve. Allowing for a 10-lb. drop through the inlet valves, the load would have been approximately 11,000 kw., when, as seen by Fig. 4, a steam consumption of less than 13.7 lb. per kw-hr. would have been obtained, with an efficiency ratio of 71 per cent.

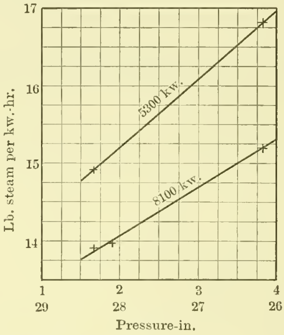

FIG. 5*a* TESTS FOR OBTAINING VACCUUM CORRECTION

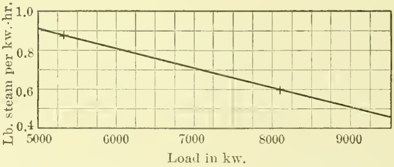

FIG. 5*b* CHANGE IN STEAM CONSUMPTION AT VARIOUS LOADS PER 1 IN. CHANGE IN VACCUUM

17 It is acknowledged that slightly superior efficiency exists with the combined engine and turbine unit, reported by Mr. Stott, at 72 per cent, the engine unit particularly making a remarkable showing. On the heat consumption basis, however, the San Francisco unit is approximately only 8½ per cent in excess of the combined reciprocating and turbine unit, but it is obvious that this advantage in steam consumption is offset by the advantage of the simple turbine unit without the complication of the reciprocating engine, which involves greater first cost, greater floor space and cost of maintenance and necessitates shutting down the unit while the reciprocator is being adjusted, or else further complicating the system by use of an auxiliary governor and high-pressure valves on the low-pressure turbine:

DETAILS OF STEAM CONSUMPTION TEST

18 As mentioned before, it was necessary to test the unit while in commercial service; consequently the loads of the turbine during the various tests were subject to variations which probably may have lowered the economy.

CORRECTIONS

19 As the operating conditions specified by contract, namely 175 lb. gage pressure, 100 deg. superheat, and 28 in. vacuum, could not be maintained throughout the test, correction factors had to be determined upon, and an agreement was reached previous to the tests as follows:

Superheat, 1 per cent change in steam consumption for 10 deg. in superheat, which is the correction factor commonly employed for turbines.

Steam Pressure, ½ per cent for 10-lb. change in pressure. (As there was no reason for the full pressure not being maintained, these were however insignificant.)

Vacuum, as the vacuum correction is affected by the design of the turbine, the amount of the correction could not be determined in advance of the tests, therefore runs *E* and *G* were made. From these and from the other tests it was found that 1 in. of vacuum affected the steam consumption 3 per cent and 6 per cent at full load and half load respectively. These vacuum corrections are shown in Fig. 5*a* and Fig. 5*b*.

20 All important readings were taken at 5-minute intervals except in cases of energy output and water measurement for which 15-minute integration proved adequate. Figs. 6 to 10 inclusive, present graphically the principal logs of the tests, which show only small fluctuations of the pressure and temperature conditions, and consistent changes in load and steam consumption, insuring reliability of the average values.

21 The electric output of the unit was obtained with a General Electric polyphase wattmeter, checked by three single-phase integrating wattmeters, tested under the supervision of Frank E. Smith, consulting engineer, and Pacific Coast representative of the Weston Electrical Instrument Company. Its complimentary current and potential transformers were similarly checked with standards.

22 Steam consumption measurements were made by actually weighing the water discharged from the surface condenser which was delivered by a 5-in. single-stage centrifugal pump through 6-in. piping to a set of four weighing tanks. These tanks were $3\frac{1}{2}$ ft. in diameter and 5 ft. deep. Each tank was on a 2000-lb. platform scale. The supply pipes and tanks were furnished with 5-in. quick-opening valves. Scales were tested and certified correct by the Howe Scale Company of San Francisco.

23 Tests were made for leakage of the cooling water into the condenser. As sea water is used for cooling, these tests were made by adding silver nitrate to samples of the condensed steam. No indications of leakage were found and hence no allowance was made for leakage.

24 The shaft glands were sealed by water taken from the condenser discharge before weighing and the leakage from outside of the glands was caught and measured. In this way no special allowance was necessary for gland sealing water. The stuffing boxes of the centrifugal hotwell pumps were sealed with water from the discharge. A small leakage occurred here which was caught and added to the leakage from the main unit gland.

25 All pipes connected with the condenser or piping system, by which water might escape from the discharge or leak into the discharge water, were disconnected, blanked or arranged with two valves with an opening between for detecting leakage.

26 Observations were made of the pressure and temperature of the steam at the throttle, pressures within the turbine at inlet, intermediate and low pressure points. The vacuum was indicated by a mercury column and the atmospheric pressure by a mercury barometer.

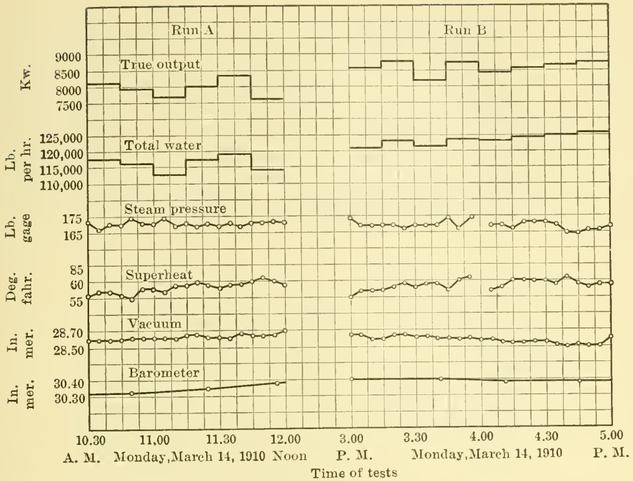

FIG. 6 LOG OF TEST DATA—RUNS A AND B

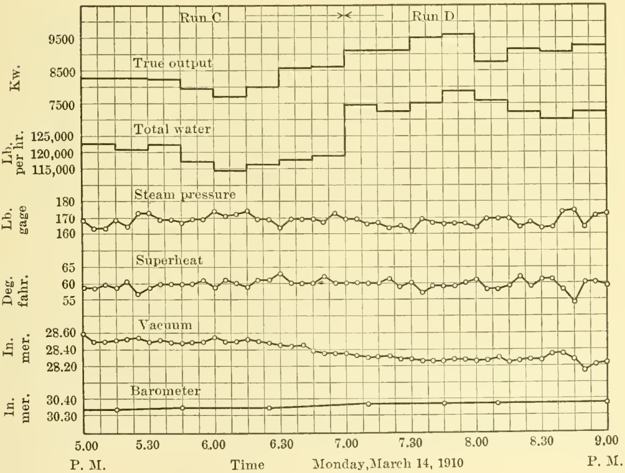

FIG. 7 LOG OF TEST DATA—RUNS C AND D

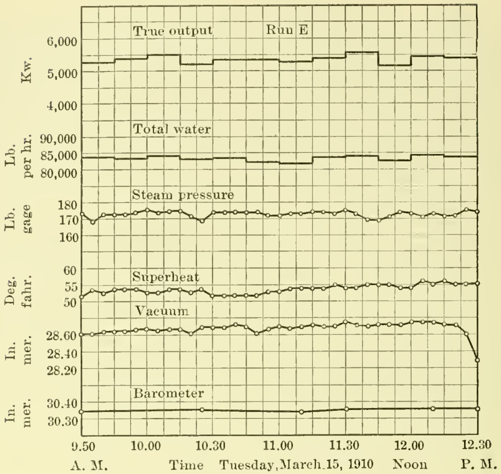

Fig. 8 Log of Test Data—Run E

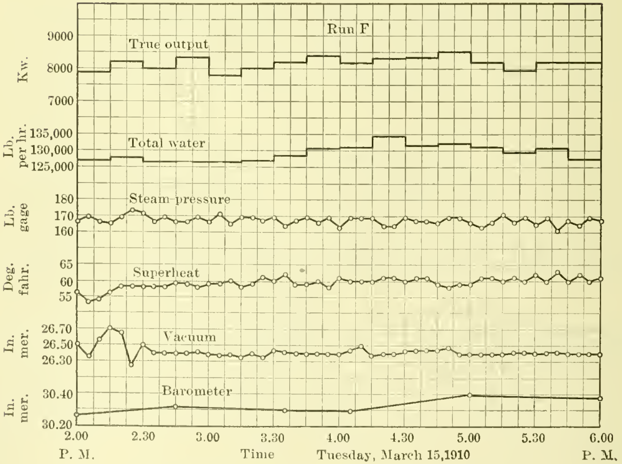

Fig. 9 Log of Test Data—Run F

The steam gages were tested on a Crosby dead-weight testing machine. The steam gage at the throttle was 1 lb. high at the working range of pressure. The steam temperatures were taken with a 15-in., 600-deg. fahr., nitrogen-filled thermometer, made by Henry Green of Brooklyn, N. Y. This thermometer was one of four new ones. As there was practical agreement of the four, by check before the tests, the temperature readings were considered practically correct. The thermometer was placed in a thermometer well in the steam pipe close to the throttle valve. The thermometer well was partly filled with mercury and the remainder of space with oil. The thermometer entered the well to the 400-deg. mark. As the steam temperature was about 430 deg., the effect of stem exposure was small. One degree has been added to the temperature for this correction.

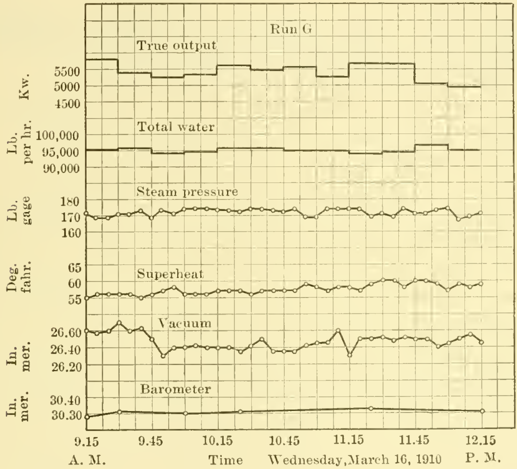

FIG. 10 LOG OF TEST DATA—RUN G

27 The vacuum gage was a Hohman and Maurer instrument. Connections were made with a $\frac{3}{4}$-in. pipe to both exhaust nozzles of the turbine. The piping was provided with a valve admitting air to blow back to the condenser any condensation in the pipe. As the mercury column has a tube of small bore, 0.1 in. or less, allowance

was made for capillary depression of the mercury by adding 0.1 in. to the average of the readings.

28 The barometer was compared with the barometer of the office of the U. S. Weather Bureau and found to be 0.1 in. low.

The following is a summary of corrections applied to readings obtained during the steam tests:

Pressure of steam supply	Subtract 1 lb.
Temperature of steam supply	Add 0.1 deg. fahr.
Vacuum column reading	Add 0.1 in.
Barometer	Add 0.1 in.

29 It would encumber the paper to publish the complete detailed logs of these tests. The author will, however, be pleased to place them at the disposal of any interested members.

TEST OF A 9000-KW. TURBO-GENERATOR SET

By F. H. Varney, San Francisco, Cal.

Member of the Society

For about five years prior to 1908 the City of Oakland had been practically dependent for its electrical energy on the water-power stations and transmission lines of the Pacific Gas and Electric Company, located 125 to 150 miles from Oakland. In the year 1908 it became evident that this service would necessarily have to be bettered, not alone for capacity, but also for regulation, and after considerable preliminary estimating, it was decided on the first day of July of that year to endeavor to have a turbo-generator set installed and operating in time for the Christmas holidays. Plans and specifications were immediately prepared and to hurry the work as much as possible a heavy bonus and penalty clause was made a part of every contract.

2 The delivery of the turbine seemed to be the one point that might cause delay, as boilers, superheaters, steam piping, condenser and all auxiliaries were promised on time. The turbine was, however, shipped 38 days in advance of promised shipment and the work progressed without delay until the unit was started and put into regular service on December 18, 1908, thus making 171 days from the beginning of the plans and specifications to the successful operation of the station. It is interesting also to know that the station, including turbo-generator, boilers, steam piping and auxiliaries, buildings, crane and everything necessary for a complete steam plant, excepting land, cost $51 per kw.

3 It was with considerable satisfaction that the turbine was started, as this was one of the driest years the water-power station had ever experienced and the demand for power greatly exceeded that of previous years.

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4 The turbine was immediately put in parallel with the hydroelectric system, which consists of eleven water-power stations, three reciprocating-engine stations, and one gas-engine plant. It operated perfectly in every particular and soon demonstrated the superiority of this class of prime mover over reciprocating steam or gas engines, both in regulation and in maintenance.

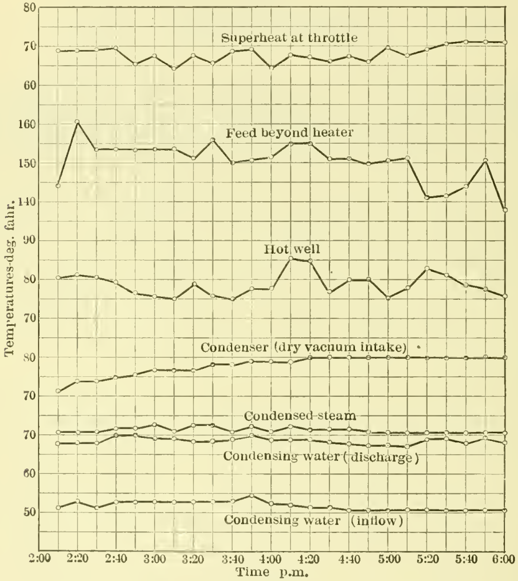

FIG. 1 LOG OF TEST DATA—FIRST TEST

5 The plant is situated on the Oakland estuary, between Grove and Jefferson Streets on First Street, distant about one mile from the center of Oakland. The estuary is a branch of the San Francisco Bay and has an ample supply of clean salt water from which circulating water for the condenser is drawn. A wharf was built into the estuary for the purpose of landing the fuel supply and the Southern Pacific Railroad tracks adjoin the First Street side of the station. The location is considered ideal.

6 The apparatus installed consists of a 9000-kw. vertical Curtis turbo-generator (maximum rated), Worthington condenser and vacuum pumps, and eight 754-h.p. McNaull water-tube boilers. The plant is oil-burning, using what is known as the back-shot burners. The boilers are equipped with superheaters for 100 deg. superheat.

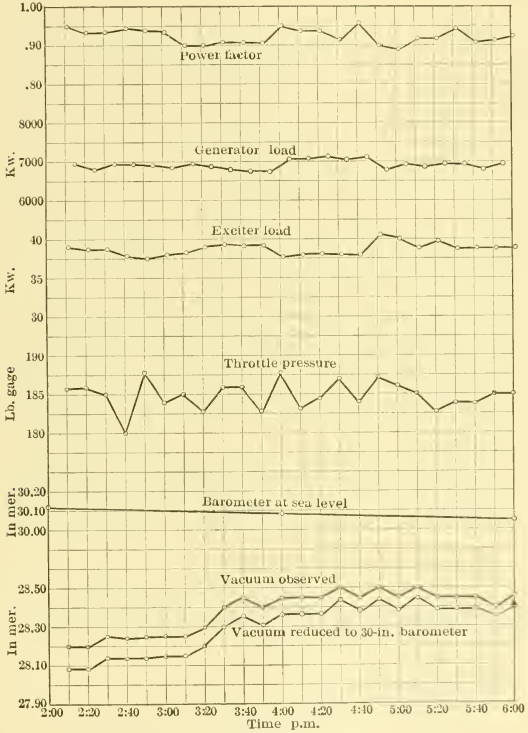

Fig. 2 Log of Test Data—First Test

7 Owing to the urgent need for the plant, the efficiency test was postponed until the station had been in operation for 14 months. The conditions of the test were as follows: The turbo-generator was run on a closely regulated commercial load, which was maintained as

nearly uniform as possible by the load dispatcher. Two runs of four hours each were made at loads approximating 7000 kw. and 9000 kw. The boilers were operated on the usual program, the number employed being adapted to the load carried. No attempt was made to obtain complete data regarding the economical operation of the boilers.

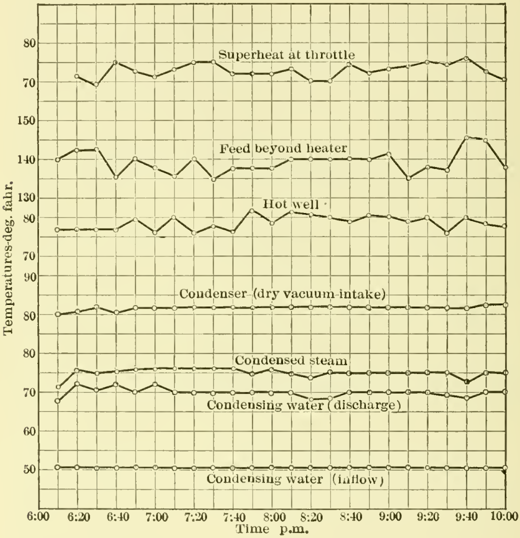

FIG. 3 LOG OF TEST DATA—SECOND TEST

8 In view of these conditions, it was decided to provide for the measurement of the following items:

a Water from turbine
b Total make-up and auxiliary water
c Power delivered by generator at switchboard
d Exciter output
e Pressures and temperatures required to complete and interpret the above observations.

9 Measurements of water were made by tank weighings with standard scales in lots averaging 1800 lb. to 1900 lb. and in accordance

with the general methods recommended by the engineering societies for such purposes. The power delivered by the generator was measured by duplicate installations of integrating wattmeters connected in accordance with the three-meter method for three-phase circuits. Observations of all electrical readings and of all pressures and temperatures were made at ten-minute intervals. Weighings of water were made at intervals as determined by the load. The level of water in the feed tank and the condition of the weighing tanks at the end of each half-hour period were also noted, thus providing for a closure of the test at any such period. Leakage tests of the condenser and of the wet vacuum pump seal were made before and

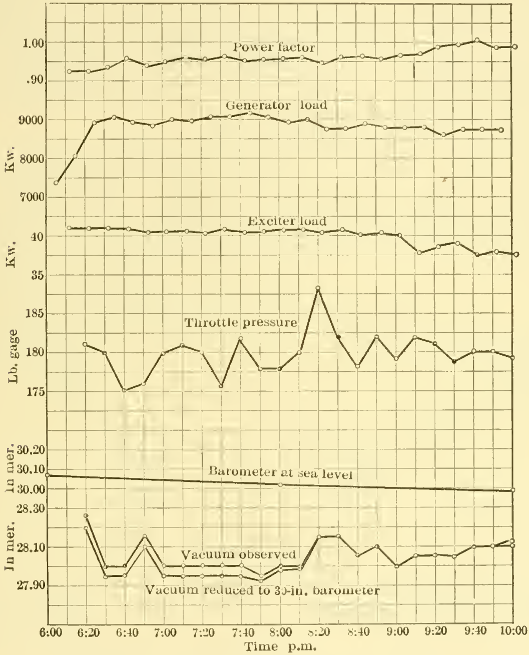

FIG. 4 LOG OF TEST DATA—SECOND TEST

after the test and a mean of the two values was used as the leakage correction.

10 All apparatus and instruments employed were carefully calibrated by reference to absolute standards or to others as near to them as possible. The scales employed were tested both before and after the run by the use of 50-lb. weights loaned for the purpose by the Fairbanks Company. All pressure gages were tested by the use of a dead-weight testing apparatus. The indications of the mercury vacuum gage were accepted as accurate without further test. The integrating wattmeters were calibrated before and after the run. All thermometers were compared with standards certified by the United States Bureau of Standards.

11 The general and economic results for each run as a whole are given below. Figs. 1 to 4 show the data worked up for ten-minute intervals and plotted on a time axis. The actual turbine results were reduced to the conditions specified in the contract, by means of the following schedule of corrections:

CONTRACT SPECIFICATIONS

1 Steam pressure at throttle	175 lb. gage
2 Superheat	125 deg. fahr.
3 Vacuum	28 in.

4 Steam consumption

Generator output (kw.)	Lb. per kw-hr.
5000	16.75
7000	16.40
9000	16.40

CORRECTIONS

1 For each 10 lb. pressure	1 per cent
2 For each 12½ lb. deg. superheat	1 per cent
3 For each inch vacuum	1.08 lb. per kw-hr.

GENERAL AND ECONOMIC RESULTS

1 Time, February 18, 1910	2.10 p.m. to 6.00 p.m.	6.00 p.m. to 10.00 p.m.
2 Total water with all corrections, lb	520,837	650,600
3 Average load, kw	6,922	8,775
4 Water from turbine as weighed (corrected for scales), lb	428,704	562,579

5 Water leakage correction, lb	−2,461	−2,568
6 Corrected water from turbine, lb	426,243	560,011
7 Water per kw-hr., lb	16.06	15.95
8 Temperature of condenser, deg. fahr	78.1	81.9
9 Temperature of condensing water, inflow, deg. fahr	52.15	51.0
10 Temperature of condensing water, discharge, deg. fahr	66.50	70.0
11 Rise in temperature of condensing water, deg. fahr	14.35	19.0
12 Vacuum in condenser, reduced to 30 in. barometer, in. mer	28.30	28.03
13 Exciter output, kw	38.9	40.0

FINAL CORRECTED VALUES

6.00 p.m. to 10.00 pm.

Correction for superheat, per cent	− 4.13
Correction for pressure, per cent	+ 0.48
Correction for superheat and pressure, per cent	− 3.65
Correction for vacuum, lb	+ 0.03
Water rate corrected for vacuum, lb	15.98
Water rate with all corrections, lb	15.42

THE FIELD FOR GRINDING

C. H. Norton, Worcester, Mass.

Non-Member[1]

Grinding in various forms has been known to man from the very beginning of history, yet it is doubtful if many engineers have a clear conception of the field for metal grinding. Experience (as a specialist) covering twenty-five years has taught me that the usual thought of grinding is that it is a slow, tedious, expensive, but sure method of obtaining accuracy, and that where great accuracy is not required grinding should not be done.

2 Webster defines abrasion as "the act of wearing or rubbing off; the wearing away by friction, as the abrasion of coins." Abrade, "to waste or wear away by friction, as to abrade rocks." He defines the word abraise as "rubbed smooth, as an abraised table," meaning a polished table. No doubt here is the connection between polishing and abrasion.

3 Some time within the last 75 to 100 years men discovered that a revolving polishing wheel enabled them to abrade work in such a comparatively short time that so far as polishing was concerned it was no longer slow nor tedious. But as the original word for abrasive action was "grind," and grinding was slow, men still clung to the tradition in spite of the later discovery that polishing could be done quickly. When, within the recollection of the writer, mechanics made their own solid glue and emery wheels with which to grind small hardened tool work, it did not occur to them that they could do by grinding a certain part of the work that they were using steel tools for, because it was grinding, and was slow. Moreover, all nice work must of necessity take lots of time, because our older mechanics

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[1] Norton Grinding Co.

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had said so. It did not occur to them that we could ever have better grinding wheels and better machines in which to use them.

4 It was at this point in our reasoning that the majority of engineers rested and it is here that we find a large number now. All engineers admit the exactness of grinding, but most of them still believe it to be slow.

5 Appleton's Cyclopædia of Applied Mechanics, published as late as 1893, says that emery wheels are employed mainly for producing cutting edges and for smoothing surfaces. Again it says that in all cases of the employment of emery wheels in place of steel cutting tools, the operation is considerably slower, and it may be laid down as a rule that save upon metal too hard to be operated upon with steel tools, the emery wheel cannot compete with the ordinary lathe, planer, milling tool, etc. My observations convince me that a great many American engineers hold the same views.

6 As a specialist for many years, I have seen a gradual but sure increase of knowledge of grinding and have noted the widening of the field as the result, but I am not aware that the intelligent study of grinding has been taken up by professional engineers or by any institute of technology. The intelligent use of grinding yields such large returns that it warrants careful study by the very best engineering and scientific minds and a place in the courses of our technical schools. The field is constantly broadening with each year's improvements in grinding wheels and grinding machines, and it is time that men of brains and education took a hand with us to help the world to a better knowledge of the science of grinding and grinding wheels.

7 The results thus far attained warrant a change of the world's idea of grinding and instead of using it as a synonym for slowness, tediousness and drudgery, it should be a synonym for rapidity, accuracy and economy.

8 The fact about grinding with the modern grinding machine and grinding wheel (not emery wheel) is that it enables us to size all round work cheaper than by turning and filing, that it takes the place of what we formerly called the finish cut of the lathe and all filing giving us not a theoretically perfect cylinder or perfect finish, but a much nearer perfect cylinder and finish that we obtained with the lathe. It gives us diameters to such small limits as to be called exact, but whoever insists that none but exact work be ground loses the very pith of grinding, which is economy. Modern grinding means cheaper cost for all work, many grades of work to suit many

requirements, and cheaper turning than is possible without the use of the grinding machine.

9 As a rule, the coarser the turning the greater the economy by grinding. The greatest economy is obtained by the combination of cheaper turning and grinding. It is no longer necessary to turn work smooth, straight or correctly to size and the lathe is no longer necessary as a precision tool. If it has a carriage traverse of from four to ten threads per inch, has sufficient power to carry high-speed tool cuts at that feed and is well supplied with steady rests to prevent springing of the work, it is ready for coöperation with the grinding machine. It is easier with modern grinding machines and wheels to grind off a given amount of metal when in the form of crude screw threads than in any other form, and with long work having several sizes the grinding requires less time if $\frac{1}{32}$ in. to $\frac{5}{64}$ in. is left on the diameter for grinding than if the work is turned carefully to within 0.002 in. to 0.005 in. In all cases, accurate turning increases the total cost of production and in some it makes the grinding very expensive.

10 The greatest economy is usually obtained by the combination of grinding with very rough turning. Yet there are cases where the least expensive way is to grind direct without turning, notably the greater part of crankshafts of automobiles and small gas engines and very long and slender work where turning is difficult.

11 It is not an easy matter to secure such rough turning as true economy requires in connection with grinding. Lack of knowledge of what is needed, coupled with the natural pride the workman takes in doing what tradition says is nice lathe work, prevents the grinding machine from doing what it is ready to do. Our industries are losing much while waiting for the engineer to assume the intelligent guidance of foreman and workmen who, through fear, doubt or prejudice now rob us of the great economies due to modern grinding machines. There is much yet to be learned by foremen and workmen about turning. High-speed steel makes possible much that has not as yet become common knowledge.

12 The lathe is a very old tool and foremen and workmen have known it for generations, yet I have been unable to find more than two instances where a careful study has been made of the combination of lathe work and grinding to effect the maximum saving. I have observed that lathe men have not tried to remove metal by increasing the number of cuts and using fast traverse. When urged to take coarse feeds to help the grinding machine to effect a total saving, they have invariably said that they were feeding all

that the work would stand. It has been demonstrated that three cuts with a carriage traverse of 6 per inch has produced certain work in 9 minutes that required 13 minutes to turn in one cut, because the work was so frail that with one cut no faster feed than 32 per inch could be taken. The rough-ridged surface was readily ground by taking 1 minute more than when the turning was finer, the net saving for the job being 3 minutes. In many cases the ridged surface requires no additional time.

13 In another case where the work was quite firm and was being revolved at a very high speed with a view to getting everything possible from the high-speed tool, the turning required 5 minutes and the grinding 1 minute. A change was made in the feed of the lathe so that without revolving the work any slower it was turned in 1 minute, leaving a very crude, crooked and bad-looking piece of lathe work. The grinding then required 2 minutes, but the net time saved was 3 minutes. Did it matter how bad a looking lathe job it was if the finished work was perfect and 3 minutes was saved?

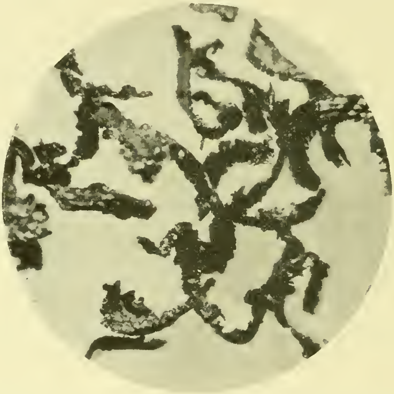

Fig. 1 Microphotograph of Chips from Modern Grinding Wheel

Note the resemblance of these fragments to lathe chips

14 There is a rich field for engineers and managers in connection with the lathe and modern grinding. Recent lathe designs provide for high speed of revolution, with sufficient power, quick change to and from back gears, and sufficient rigidity to utilize to the limit

high-speed steel; but much work is not of sufficient rigidity to permit the maximum use of the tool at fast traverse and deep cuts. In addition, there are thousands of lathes of old design that will not be thrown away at once. There is, therefore, an opportunity to get much more out of present plants by cheaper turning, *because of grinding.*

15 Developments warrant the conclusion that we should no longer assume that simply because a tool is a grinding wheel it cannot remove metal and size and shape work as quickly as a steel tool. Rather, we should use the steel tool when it can be made to remove metal, size and shape work cheapest, and the grinding wheel when it excels. It is no longer to be taken as a matter of course that we can turn, plane and mill faster than we can grind. After all, the real reason we remove metal is to accomplish certain finished results, not simply to secure a certain number of pounds of chips in a given time. Before long I think all progressive engineers will understand that both the grinding wheel and the steel tool have their place for metal cutting. The old thought of abrasion must give way to the new thought of cutting.

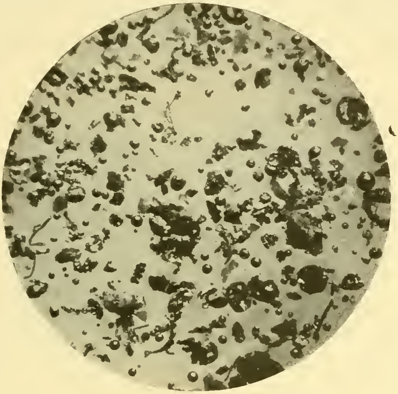

Fig. 2 Microphotograph of Fragments from Emery Wheel

Many of the particles are melted by the heat generated in grinding

16 While it is still true that poor wheels or good wheels poorly selected and wrongly used will still remove metal very slowly by

abrasion, it is also true that the old-fashioned milling cutter, with fine teeth cut by hand with a file, hardened but never ground, and used in the old-time slender milling machine would very slowly abrade the surface. The modern grinding wheel, used in a modern machine by a modern man, is just as surely a milling cutter as if it were made of steel.

17 The microscope reveals the fact that such a wheel cuts off chips. Fig. 1 is from a microphotograph and clearly shows the chips that are as surely cut off as those made with a steel milling cutter. The grinding wheel used was a modern one made of crystalline aluminum oxide.

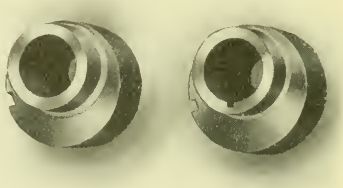

Fig. 3 Fig. 4

First Two Stages in the Grinding of an Automobile Cam

18 Fig. 2 is also from a microphotograph and shows the result of the old-fashioned abrasion described by Webster as grinding to powder. Here we see the effect of great heat, the greater part of the powder being in the form of globules. This is magnified to the same extent as the other photograph and shows the vast difference between the old-time abrasion to powder and the present cutting chips. A large part of the energy put into work was wasted in heat, as shown by the very small globules in Fig. 2. The wheel used for Fig. 2 was an emery wheel like those referred to in Appleton's Cyclopædia of 1893.

19 The grinding wheel as now made is really a milling cutter with millions of cutting teeth. Although these teeth are not as large or as strong as the teeth of a steel cutter and therefore cannot cut as

deeply, yet they are capable of cutting at much greater speed. Since there are so many more of them they are capable of much more work in a given time when the nature of the work is such that a large number of these cutting points can be used simultaneously. In some cases we can use as many as two billion cutting points per minute. Eight hundred million per minute is not uncommon and four hundred million per minute is very common.

20 The modern grinding wheel, mounted in a good machine, can be used at a cutting speed of 6000 or more surface feet per minute and owing to this high speed it need not cut deeply relative to the rigidity of the work. Therefore it is able to remove metal from many forms of work more quickly than the milling cutter or the lathe tool.

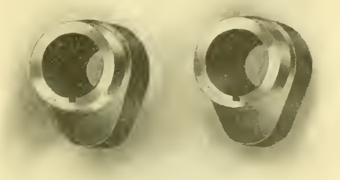

Fig. 5 Fig. 6

Last Two Stages in the Grinding of an Automobile Cam

21 The accompanying illustrations show a notable example. Figs. 3, 4, 5 and 6 show the process of making automobile cams. An order for a hundred of these cams was received and our shop superintendent began to provide means for producing them at the lowest possible cost. It is evident that drop forgings for so few would be out of the question, as the expense of dies would make the cost of the cams prohibitive. It was therefore necessary to devise means for producing them from the bar stock. This was done by providing an eccentric chuck for the automatic screw machine. To prevent the bar from turning in the chuck while feeding forward, the spline was made the full length and a mating key was placed in the chuck. Pieces like

Fig. 3 were made in the automatic machine at the rate of 10 per hour. A keyway in the hole was made in the ordinary way, Fig. 4. These blanks were ground to rough shape, Fig. 5, at the rate of 10 per hour. The cams were then hardened and finished ground to Fig. 6 at the rate of 40 per hour. It should be clear that such a cam could not be milled to shape from the blank in nearly so short a time with the milling cutter. When manufacturing such cams in large numbers drop forgings would be used, and here again the grinding wheel is quicker than the milling cutter.

22 Another case where the grinding machine can accomplish the results desired in less time than the lathe is that of the pins and bearings of the automobile crankshaft. The results desired are as follows:

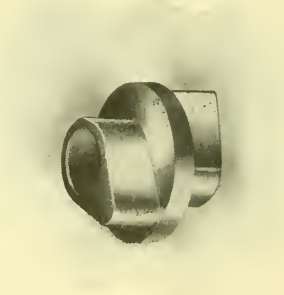

Fig. 7 Double Cam Ground from Rough Stock 2 In. in Diameter

Five bearings, all round within 0.00025 in.; the axis of all parallel and exactly in line; all of the right length within 0.004 in.; distance between bearings within 0.004 in.; accumulated error not over 0.008 in. Four crank pins, all round within 0.00025 in.; the axis of all exactly parallel; all to length within 0.004 in.; all parallel with the bearings; all within 0.005 in. of the same plane; all of correct throw, within 0.010 in.; overall length, accumulated error not over 0.008 in.; all fillets correct radius and exactly concentric with the bearings and pins; all bearings and pins straight within 0.00025 in.; and all a good, smooth surface.

23 In the case of cranks designed with clearance for the arms of the cranks, as shown in Fig. 8, the width of the wheel is identical with

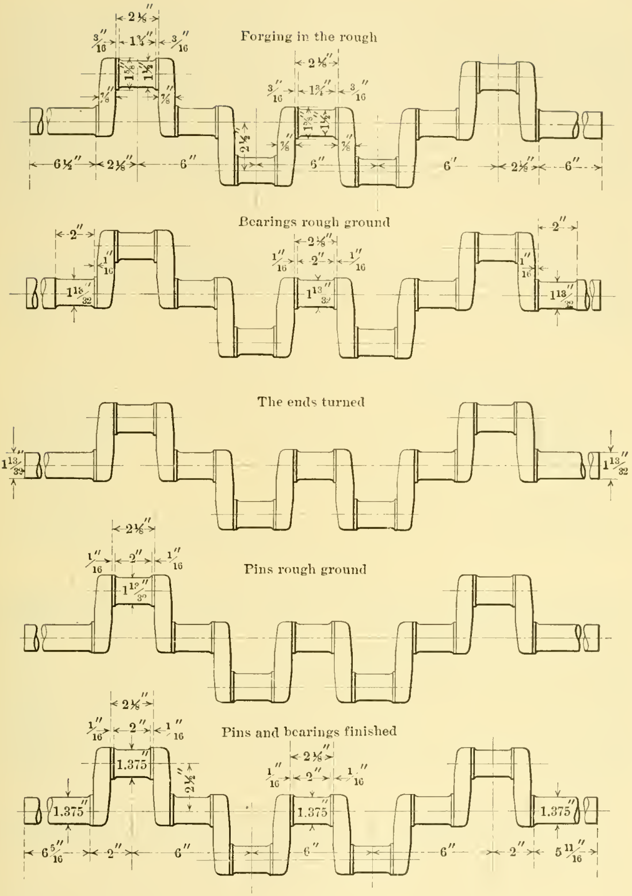

Fig. 8 Stages in the Grinding of an Automobile Crankshaft

the required length of the pins and bearings, so that no measuring or setting of the tool is necessary for cutting to length. The act of grinding cuts the bearing or pin the right length and forms the fillets.

The location of the pins and bearings within the small limits allowed is accompanied by a massive index bar, so that the workman does no measuring whatever for location of bearings or pins. The entire time of handling and producing these five bearings and four pins from the rough forging to the nicely-sized and finished condition is 85 minutes. It is clear that when all the conditions of the finished work are considered the grinding wheel and machine have removed metal faster than the lathe. Again, it is not simply a case of removing pounds of metal per hour, but the removal of it in such a manner as to accomplish certain results in the least time.

24 The ends of these shafts beyond the bearings are turned before grinding. The entire list of operations to make a finished shaft from the forging is as follows:

Cut off ends and center	6 minutes
Rough grind bearings	15 minutes
Turn ends	8 minutes
Rough grind pins	20 minutes
Finish grind pins	20 minutes
Finish grind bearings and ends	25 minutes
Square ends	6 minutes
Total time	100 minutes

A little time could be saved if it were practical to secure forgings with pins and bearings $1\frac{5}{8}$ in. in diameter over their entire length instead of with the depression to $1\frac{1}{2}$ in. between shoulders, as the wheel can be forced more rapidly when the face has the same amount of work to do as the fillets. Here again tradition is strong and difficult to change at once, because the depression is better for those who turn the work. A little coöperation would save on dies and time in grinding.

25 There are hundreds of other cases where the grinding wheel is used to remove metal in a more economical manner than with steel-cutting tools, some of which are shown in Figs. 9 to 19.

26 Automatic grinding is a late development in the field. Certain work of which large numbers of pieces are made is ground by wholly automatic means. The work is conveyed to the machine by gravity in a hopper or shute and is chucked, ground and delivered to the receptacle. In a case where formerly, at piece work, 300 per day were ground, the automatic machine grinds 4 in a single minute, about 2300 per day.

27 When the knowledge of grinding becomes more common and the opposition to increased production on the part of the workmen shall have been more nearly overcome, the field will be still more extended. It is worthy of more systematic coöperation and if we get together we will be rewarded with success. The engineer is the one who by education and training is best fitted to take up the important question of the field for grinding.

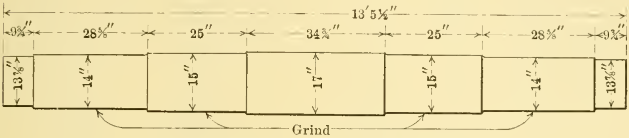

Fig. 9 Engine Shaft—Hammered Forging

Weight, 8000 lbs.; stock removed, 0.025 in.; limit, 0.001 in.; time, 6 hr. (8 hr. including handling)

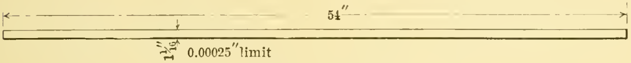

Fig. 10. Shaft 0.30 Carbon Steel

Stock removed, $\frac{1}{16}$ in.; limit, as noted; time, 1 hr. (including setting up)

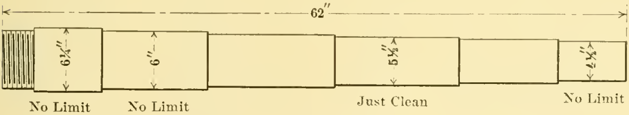

Fig. 11 Lathe Spindle—Crucible Steel, Hardened

Stock removed, 0.035 in.; limits, as noted; time, 1½ pieces per hr.

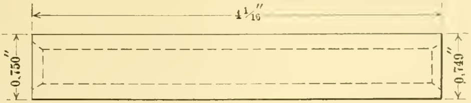

Fig. 12 Piston Pin—0.15 Carbon Steel, Hardened

Stock removed, 0.015 in.; limit, 0.0005 in.; time, 60 pieces per hr.

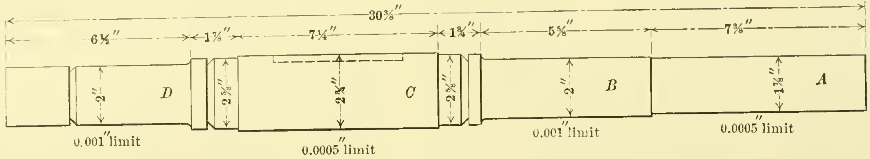

Fig. 13 Armature Shaft—0.30 Carbon Steel

Stock removed, $\frac{3}{64}$ in.; limits, as noted; time, 3 pieces per hr.

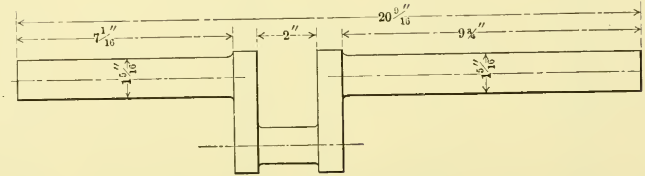

Fig. 14 Crankshaft—0.45 Carbon Steel

Grind bearings only; stock removed, 0.015 in.; limit, 0.0005 in.; time, 50 in 7 hr. 15 min.

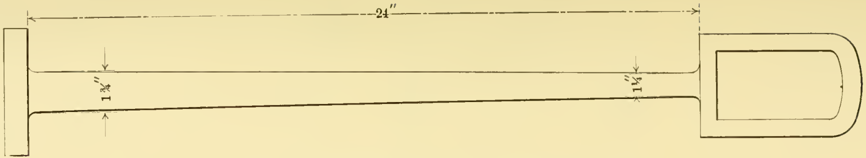

Fig. 15 Connecting Rod—0.30 Carbon Steel

Stock removed, 0.008 in.; limit, just cleaned; time, 25 pieces per hr.

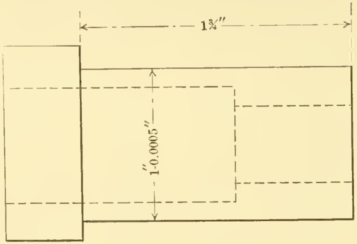

Fig. 16 Bushing—Cast Iron

Stock removed, 0.010 in.; limit as noted; time, 45 pieces per hr.

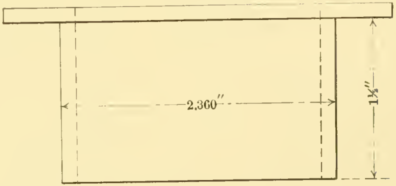

Fig. 17 Bushing—Pressed Steel

Stock removed, 0.025 in.; limit 0.0005 in.; time 60 pieces per hr.

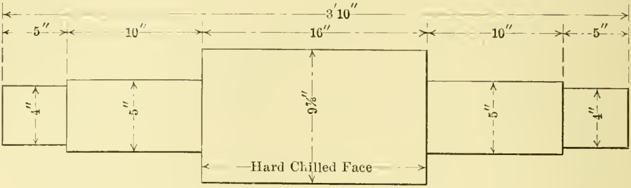

FIG. 18 CHILLED ROLL—CHILLED IRON

Stock removed, ⅜ in.; time roll face, 2½ hr.; previous lathe time 12 hr.

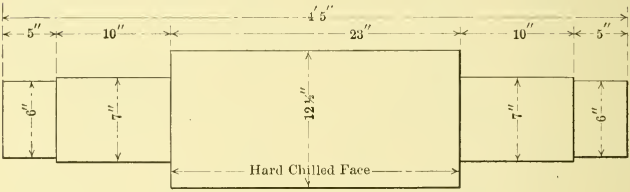

FIG. 19 CHILLED ROLL—CHILLED IRON

Stock removed, ½ in.; time roll face, 7 hr.; journals and ends, 3½ hr.; total, 10½ hr.; lathe time for same work, 23 hr.

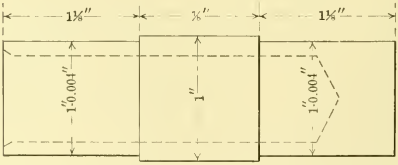

FIG. 20 PISTON PIN—MACHINE STEEL, HARDENED

Stock removed, 0.015 in.; limit, 0.0005 in.; time, 25 pieces per hr.

PRECISION GRINDING

By W. A. Viall, Providence, R. I.

Member of the Society

Grinding is an art rather than an exact mechanical operation. It is an art of such recent growth that relatively little is known about it or its possibilities. In the development of the grinding machine from the early beginning, as described in the historical article in Machinery of July 1910, to the present well-known makes of universal and plain grinding machines, the successive steps that have been taken toward reaching stability and convenience in the machine form interesting chapters of mechanical history, since they show, as well as any class of machines, the tendency of the times.

2 In speaking of grinding as an art I mean that it contains elements in which the judgment and experience of the operator count for a great deal. While in a general way the manufacturer or the skilled operator is able to give instructions for the running of the machines, yet conditions arise which make it necessary to vary from these instructions in order to obtain the best results. To instruct an operator to use a given wheel and speed would make it possible for him to obtain any one of the three results. When ground with a wheel surface that is not true a piece looks as though it had been gouged upon a grindstone, while with a wheel surface that is true it gives a dull finish and shows the wheel marks. The latter is what we consider commercial grinding. When this same wheel has been run so that the points of the abrasive become somewhat dull, we obtain a highly-finished surface. All these results are possible with the same wheel under different conditions.

3 Most of us are interested in two classes of grinding, One is the occasional grinding such as we find in the tool room and in the shop

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

where one or two pieces of a kind are made and where accurate fits are demanded. The second is the manufacturer's problem where not only must the nicest accuracy be obtained but where the rate of production is an important consideration. In the first case the question of cost does not enter so deeply into the problem, although it is always to be considered; and one machine, specially designed to do a certain class of work, is often compelled to answer the necessities for work to which it is not well suited. In the second case, however, the best results as to efficiency and production are obtained by having a machine of the proper size. It must be understood from the first that whether the machine is large or small it must be sufficiently heavy and stable enough to do the work it is called upon to do and it must be so designed that it can readily be operated. This latter element of convenience must be provided for even more carefully than in many other classes of tools, because much of the work done in the grinding machine is of such a character that the operations of putting in and taking out consume almost as much time as the grinding. Moreover, a grinding machine must have sufficient rigidity to preserve its alignment, which must be of a high grade from the first. Unless the machine is capable of producing true work its value is lost, for the grinding machine must not only finish work but also rectify it to a degree of accuracy that we cannot in reason look to a lathe or other type of machine to furnish commercially.

4 The principles of grinding, in the main, are not difficult to grasp, and the time that would be required of the ordinary chief operator in grasping them is not excessive. But the work does require such attention and knowledge of the results that can be obtained, coupled with the skill acquired by experience, as to class it with the Arts. In the early days it seemed quite necessary that for every different piece of work we should have a different wheel. Later it was found that a given wheel would give satisfactory results on various kinds of work by varying the speed of the wheel, the speed at which the work was run, or the feed of the work, so that one wheel answered a great variety of purposes. There have been changes in abrasives and we are getting today a far better quality of wheel than was possible some years ago. The grading of wheels has very much improved, and although in the writer's opinion it is not possible to obtain an absolute grading, this element has been reduced to such a nicety that it need not be taken largely into account by the average operator.

5 The first use of the grinding machine as we know it today

was to correct slight errors that were impossible of eradication by means of the file and emery cloth. Today the grinding machine rectifies these errors and in addition finishes work for appearance and fit in a relatively cheap manner.

6 After the proper machine has been selected, the choice of wheels requires some specialized knowledge which the makers of machines and wheels are in a position to furnish to an extent that many of the users of machine tools are probably not aware. When the proper wheels and gradings are once established for a given line of work their subsequent use is very easy.

7 The question of speeds and feeds is also the result of experience, and suggestions from the manufacturers will help users to a great extent in obtaining satisfactory results. The cutting operation of the wheel was well shown in an illustrated article by Messrs. Gribben and Warman[1] where the microscopic photographs showed that the chips somewhat resembled those made by a lathe tool. It is only under proper conditions, however, that these results can be obtained. The wheels must be true and they must not be forced into the work to too great an extent, for this produces a torn effect upon the work, which is to be avoided.

8 In considering a piece of work to be done, first of all the question arises as to the size and the limits suitable for the purpose for which it is intended. Table 1 gives the limits used at the Brown & Sharpe Mfg. Co.'s works for varying conditions. There are special cases where it may be necessary to increase or to decrease these limits, and this table is not offered as the final word but as a guide towards selection.

9 The second necessity is that sizes should be established to which the work should be rough turned ready for the grinding room. In our works, as in all factories, the aim is to produce the desired results as cheaply as possible. Our desired ends have been accuracy and nicety of finish where the parts ground are for fits, and nicety of finish where no fit is required. To do this work as cheaply as possible we believe that it is economical to turn the pieces to about the sizes indicated in Table 2. It will be noted that we allow from 0.008 in. to 0.012 in. in diameter, an amount easily obtained by the ordinary class of lathe help. In order to make this work as easy as possible for the lathe department, we furnish the limit gage shown in the sketch. We are aware that practice varies on this point, and we have thoroughly

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[1] American Machinist, July 2, 1903.

TABLE 1 GRINDING LIMITS FOR CYLINDRICAL PIECES[1]

As Adopted by Brown and Sharpe Mfg. Co.,

RUNNING FITS—ORDINARY SPEED

To ½-in. diameter, inc.	0.00025 to 0.00075	Small
To 1 -in. diameter, inc.	0.00075 to 0.0015	Small
To 2 -in. diameter, inc.	0.0015 to 0.0025	Small
To 3½-in. diameter, inc.	0.0025 to 0.0035	Small
To 6 -in. diameter, inc.	0.0035 to 0.005	Small

RUNNING FITS—HIGH SPEED, HEAVY PRESSURE AND ROCKER SHAFTS

To ½-in. diameter, inc.	0.0005 to 0.001	Small
To 1 -in. diameter, inc.	0.001 to 0.002	Small
To 2 -in. diameter, inc.	0.002 to 0.003	Small
To 3½-in. diameter, inc.	0.003 to 0.0045	Small
To 6 -in. diameter, inc.	0.0045 to 0.0065	Small

SLIDING FITS

To ½-in. diameter, inc.	0.00025 to 0.0005	Small
To 1 -in. diameter, inc.	0.0005 to 0.001	Small
To 2 -in. diameter, inc.	0.001 to 0.002	Small
To 3½-in. diameter, inc.	0.002 to 0.0035	Small
To 6 -in. diameter, inc.	0.003 to 0.005	Small

STANDARD FITS

To ½-in. diameter, inc.	Standard to 0.00025	Small
To 1 -in. diameter, inc.	Standard to 0.0005	Small
To 2 -in. diameter, inc.	Standard to 0.001	Small
To 3½-in. diameter, inc.	Standard to 0.0015	Small
To 6 -in. diameter, inc.	Standard to 0.002	Small

DRIVING FITS—FOR SUCH PIECES AS ARE REQUIRED TO BE READILY TAKEN APART

To ½-in. diameter, inc.	Standard to 0.00025	Large
To 1 -in. diameter, inc.	0.00025 to 0.0005	Large
To 2 -in. diameter, inc.	0.0005 to 0.00075	Large
To 3½-in. diameter, inc.	0.00075 to 0.001	Large
To 6 -in. diameter, inc.	0.001 to 0.0015	Large
To ½-in. diameter, inc.	0.0005 to 0.001	Large

DRIVING FITS

To 1 -in. diameter, inc.	0.001 to 0.002	Large
To 2 -in. diameter, inc.	0.002 to 0.003	Large
To 3½-in. diameter, inc.	0.003 to 0.004	Large
To 6 -in. diameter, inc.	0.004 to 0.005	Large
To ½-in. diameter, inc.	0.00075 to 0.0015	Large

FORCING FITS

To 1 -in. diameter, inc.	0.0015 to 0.0025	Large
To 2 -in. diameter, inc.	0.0025 to 0.004	Large
To 3½-in. diameter, inc.	0.004 to 0.006	Large
To 6 -in. diameter, inc.	0.006 to 0.009	Large
To ½-in. diameter, inc.	0.00025 to 0.0005	Large

SHRINKING FITS—FOR PIECES TO TAKE HARDENED SHELLS ⅜-IN. THICK AND LESS

To 1 -in. diameter, inc.	0.0005 to 0.001	Large
To 2 -in. diameter, inc.	0.001 to 0.0015	Large
To 3½-in. diameter, inc.	0.0015 to 0.002	Large
To 6 -in. diameter, inc.	0.002 to 0.003	Large
To ½-in. diameter, inc.	0.0005 to 0.001	Large

SHRINKING FITS—FOR PIECES TO TAKE SHELLS ETC., HAVING A THICKNESS OF MORE THAN ⅜-IN,

To 1 -in. diameter, inc.	0.001 to 0.0025	Large
To 2 -in. diameter, inc.	0.0025 to 0.0035	Large
To 3½-in. diameter, inc.	0.0035 to 0.005	Large
To 6 -in. diameter, inc.	0.005 to 0.007	Large
To ½-in. diameter, inc.	Standard to 0.0005	Large

GRINDING LIMITS FOR HOLES

To 1 -in. diameter, inc.	Standard to 0.00075	Large
To 2 -in. diameter, inc.	Standard to 0.001	Large
To 3½-in. diameter, inc.	Standard to 0.0015	Large
To 6 -in. diameter, inc.	Standard to 0.002	Large
To 12-in. diameter, inc.	Standard to 0.0025	Large

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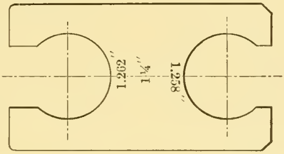
[1] The limits given in the table can be recommended for use in the manufacture of machine parts to produce satisfactory commercial work. These limits should be followed under ordinary conditions. Special cases should always be considered, as it may be desirable to vary slightly from the tables

endeavored to try out the plan of allowing correct limits, but we have found it fully practicable to hold the lathe to the limits given. By so doing we obtain the finished product free from all tool marks and at what we believe is the minimum cost.

10 Figs. 1 to 6 show some samples of commercial grinding taken from actual practice for the purpose of giving an idea of what can be done in a commercial way, as well as to give some definite data as to speeds, feeds, etc. While it is perhaps not possible to give a rule that will fit all work, these plates should suggest ideas that will help in producing the work as well and as cheaply as this has been done in the cases shown. When enough pieces of any one kind are to be made it is possible to specialize to a higher degree than can be done in the general run of work, and better results may be obtained than are shown here.

TABLE 3 LIMIT GAGES FOR LATHE WORK



Size	Not Go On	Go On	Size	Not Go On	Go On	Size	Not Go On	Go On
Inches			Inches			Inches		
3/8	0.383	0.387	15/16	0.9455	0.9495	1 1/2	1.508	1.512
7/16	0.4455	0.4495	1	1.008	1.012	1 9/16	1.5705	1.5745
1/2	0.508	0.512	1 1/16	1.0705	1.0745	1 5/8	1.633	1.637
9/16	0.5705	0.5745	1 1/8	1.133	1.137	1 11/16	1.6955	1.6995
5/8	0.633	0.637	1 3/16	1.1955	1.1995	1 3/4	1.758	1.762
11/16	0.6955	0.6995	1 1/4	1.258	1.262	1 13/16	1.8205	1.8245
3/4	0.758	0.762	1 5/16	1.3205	1.3245	1 7/8	1.883	1.887
13/16	0.8205	0.8245	1 3/8	1.383	1.387	1 15/16	1.9455	1.9495
7/8	0.883	0.887	1 7/16	1.4455	1.4495	2	2.008	2.012

11 The examples of commercial grinding given in Figs. 1 to 6 illustrate what is being done under actual working conditions in commercial work on the variety of pieces indicated, which are of various materials, both soft and hard. A reversal of the usual rule, where economy is

TABLE 3 EXAMPLES OF COMMERCIAL GRINDING

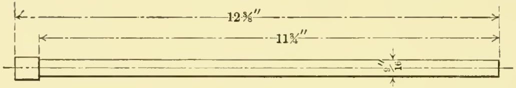
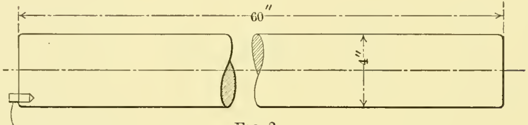


FIG. 1



Plug to drive work
when grinding

FIG. 2

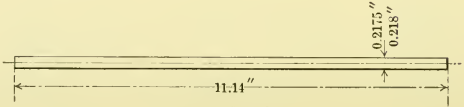


FIG. 3

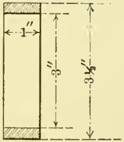


FIG. 4

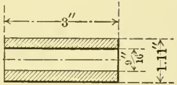


FIG. 5

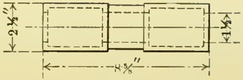


FIG. 6

Fig. No.	1	2	3	4	5	6
Material	Soft machinery steel	Machinery steel	Machinery steel, case-hardened	Machinery steel, case-hardened	Cast iron	Bearing bronze
Part Ground	External	External	External	Internal	External	External
Machine Used	No. 11 Plain	No. 28 Plain	No. 11 Plain	No. 1 Universal (Special)	No. 11 Plain	No. 14 Plain
Wheel Used	Monarch, 12 in. × 1 in. Corundum, No. 46, grade $2\frac{1}{4}$	Norton, 24 in. × 2 in. Alundum, No. 3846, grade K	Norton, 12 in. × $\frac{1}{2}$ in Alundum, No. 36, grade 5, elastic	Norton, $2\frac{1}{2}$ in. × 2 in.; Alundum, No. 5, grade $2\frac{1}{2}$ elastic	American, 12 in × 1 in., Corundum, No. 46, grade K	Abrasive, 18 in. × $1\frac{1}{2}$ in., Corundum, No. 60 grade L
Periphery Speed of Work, Ft. per Min.	35	35 roughing; 60 finishing	35	100	55	75
Travel of Work, In. per Min.	96	48 roughing; 30 finishing	13	By hand	37	30
Periphery Speed of Wheel, Ft. per Min.	7000	6000	5500 to 6000	5500	6500	6000
Amount of Stock Removed, Diameter.	0.012 in. roughing, 0.005 in. finishing	0.025 in. roughing, 0.005 in. finishing.	0.005 in. roughing; 0.001 in. finishing	0.018 in. to 0.020 in. 0.010 in. to 0.010 in.	0.020 in. to 0.025 in.	0.012 in. to 0.015 in.
Number of Pieces Completed per Hr.	13	3.5	15	16 20	54	32 1 man 59 2 men*
Required Limit	Standard to 0.00025 in. small	Standard to 0.001 in. small	Standard to 0.0005 in. small	Standard to 0.0005 in. large	Standard to 0.0005 in. small	Standard to 0.0005 in. small
In Lots of	100	50	500	200	200	100
Remarks	21 roughed; 35 finished per hr. Handled twice	7 roughed; 7 finished per hr. Handled twice	Handled twice roughing and twice for finishing			*A man operates the machine and a helper puts the work on and off the arbor

gained by having one man operate more than one machine, is shown in Fig. 6, where work is most economically produced by using two men to run one machine, that is, having one man to operate it and a helper to drive the work on and off the arbor. All other data are based on one man to a machine.

12 These pieces passed inspection within the limits given. The average loss from work of this class coming below the required limit or being otherwise spoiled is less than ¼ of 1 per cent in our grinding department.

13 Figs. 7 to 13 are each notated to show the peculiar features that exist in the work, together with the data that may be of help in deciding upon other work of this class.

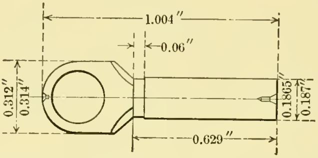


Fig. 7 Sewing-Machine Plunger—Case Hardened

This piece is ground at the rate of 145 per hour. Only a small amount 0.006 in., is taken off to prevent grinding below the case-hardened surface. Ground on No. 11 plain grinding machine. As this piece is only about 1 in. long it is quite difficult to handle, and this somewhat reduces the output.

An elastic wheel 36, grade 5 is used; speed of wheel, about 6000 ft. per min; speed of work, about 35 ft. per min.

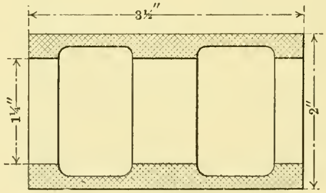


Fig. 8 Bronze Bushing

These bushings are ground at the rate of 30 per hour. Ground on No. 12 or No. 14 Plain Grinding Machine.

About 0.020 in. of stock is removed from the diameter. A 54 grade M American wheel is used; speed of emery wheel, about 6500 ft. per min.; speed of work, about 70 ft. per min.

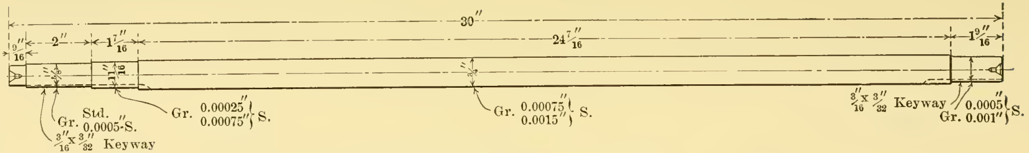


FIG. 9 SHAFT OF MACHINERY STEEL

These shafts can be finished down to size at the rate of 3 per hour. Between 0 010 in and 0.015 in. of stock is removed from the diameter. A Norton wheel, 3836 combination L, is used.

Speed of emery wheel, about 7000 ft. per min.

Speed of work, about 55 ft. per min. Ground on No. 11 Plain Grinding Machine.

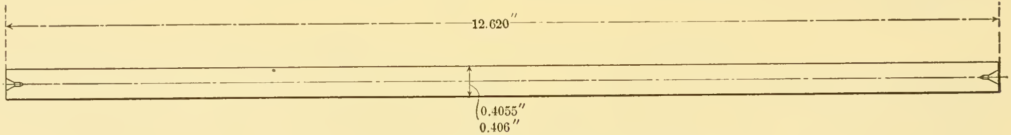


FIG. 10 SEWING-MACHINE SHAFT—CASE HARDENED

These pieces are ground at the rate of 15 per hour. They are turned end for end for dogging in both the roughing and finishing operation; thus they are handled four times to complete. Only about 0.006 in. is left for grinding to prevent grinding under the case-hardened surface. These shafts are rough ground where there is so small an amount of stock for the purpose of breaking the scale the entire length before finishing. They are held to a limit gage ("Go on" and "Not go on"), and must be ground straight. An elastic wheel 36 grade 5 is used.

They are run through in lots of 500.

Speed of wheel, about 6000 ft. per min.

Speed of work, between 30 and 35 ft. per min.

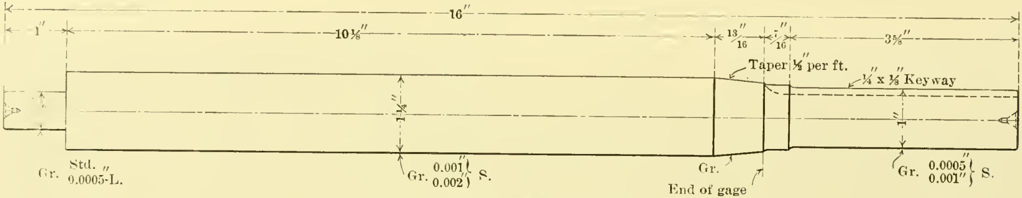


FIG. 11 SHAFT OF MACHINERY STEEL

This is a very difficult shaft to grind on account of the small diameter at one end, which gives a very poor support for grinding the larger diameters. It therefore takes about 1½ hr. to finish one shaft.

The $2\frac{5}{16}$-in. diameter is roughed out first so that a back rest can be used. Each shaft is handled 6 times before it is finished, and from 0.015 in. to 0.018 in. of stock is taken off.

Speed of wheel, about 7000 ft. per min.

Speed of work about 45 ft. per min. Ground on No. 12 or No. 14 Plain Grinding Machine.

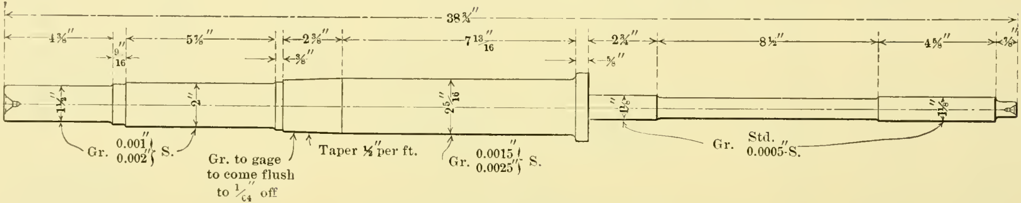


FIG. 12 SHAFT OF MACHINERY STEEL

These shafts are ground at the rate of about 5 per hr. They cannot stand heavy cuts on account of having a small diameter at one end. The taper is ground to a gage and must be concentric. Each piece is handled four times before it is finished.

Speed of emery wheel, about 7000 ft. per min.

Speed of work, about 65 ft. per min.

Ground on No. 12 Plain Grinding Machine.

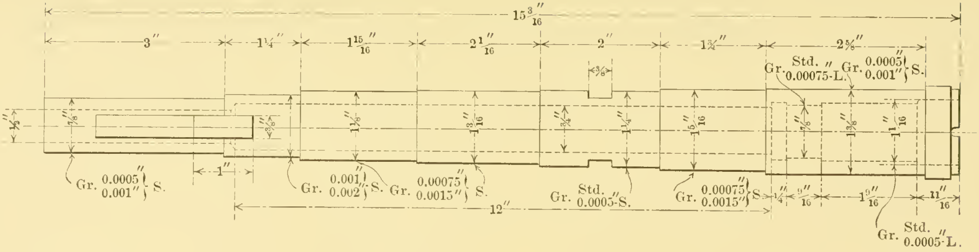


Fig. 13 Spindle of Union Drawn Steel—Case Hardened

This spindle is ground both externally and internally. It is rough ground and then finish ground all over. A Monarch wheel 46 2¼ or a Norton wheel 3846 grade K is used. A very fine finish is produced. Note hole running entire length of spindle, also where cut away near small end and near middle, all of which adds to the problem of grinding.

One man grinds these spindles in lots of 50 in a little less than ½ hr. each. Actual time 50, in 24 hr. From 0.015 in. to 0.025 in. of stock is left on diameter for grinding and 0.003 in. or 0.004 in. is left for finish grinding. These spindles are ground internally on two diameters to a very close limit. These two holes must be exactly concentric and are therefore ground at one setting, at the rate of 3 per hr. Each spindle is handled 12 times before completion.

Ground on a No. 11 Plain Grinding Machine, and on a No. 2 Universal Machine for internal grinding.

MODERN GRINDING METHODS

By B. M. W. Hanson, Hartford, Conn.

Member of the Society

One of the oldest, perhaps the oldest, means for reducing material for the purpose of giving it the desired shape, is by grinding. Our ancestors ground their stone axes and arrow points against a rock, by rubbing them back and forth. The next advance in grinding was probably the revolving of a stone on an axle turned by a crank. It was soon discovered that by having water running on a stone, the grinding could be done faster. This discovery was probably made by accident, since at that time nobody would have thought of the reason so long as results were obtained.

2 Grinding had then advanced to a point where the grinding member revolved in a fixed position, but the piece to be ground was held in the hands of the operator, and by manipulating it at different angles to the grinding surface, a shape was obtained which met the requirements reasonably well. The art seems to have remained at this stage for centuries and not until the lathe and other machine tools had been in use for a long time was it thought to hold the piece of work in a fixed position against a revolving grinding member also having a fixed position.

3 The grinding machine as now used is of comparatively recent origin, within the memory of men now living. The first grinding machines suggestive of modern methods of grinding were made in England and America, but it is in America that they have reached their highest development.

4 The invention of emery wheels made it possible to make fairly rapid progress with grinding processes. At first very little work was ground which could be machined and filed. The process of grinding was confined to pieces of hardened steel, but after awhile it was discovered that unhardened pieces could be machined and finished more

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The American Society of Mechanical Engineers, 29 West 39th Street, New York. All papers are subject to revision.

accurately and cheaply by grinding process than by finish turning and filing.

5 The grinding machine for cylindrical surfaces was developed to meet all strains and forces due to the cutting power of the shellac emery wheel; but when corundum and carborundum wheels were put in use it was found that the machinery was not quite strong and heavy enough to resist their cutting power or to resist the vibration. Within the last few years great improvements have been made not only in the cutting quality of grinding wheels, but in the design of the machines themselves; in fact, grinding machinery has become a formidable competitor of the lathe and milling machine and seems to be quite up to the cutting capacity of the wheels.

6 The designers of grinding machinery have had a good many problems to solve. Different materials require different speeds and on the modern grinding machine there must be various speeds for the grinding member as well as for the traverse movement of the work; and for the revolution of the work in the case of the cylindrical grinder. Machines must be designed with water pumps, and the working parts must be protected from water as well as from the grit which comes from the grinding wheel. The grinding member usually moves at a high rate of speed and must have carefully designed bearings which will run freely, yet not allow any back lash, as true surfaces can only be obtained when the work and the reducing member move against each other in fixed positions. Most of these difficulties have been met and further refinements are constantly being made. I will give a few illustrations of such improvements further on.

7 The grinding machines now used can be divided into two large groups; machines for cylindrical grinding and machines for grinding flat surfaces. Cylindrical grinders are well known and have been highly developed by four machine-tool builders in this country. The other style of grinder, the surface grinder, is best known as a planer type machine, with a wheel grinding on its periphery, and fed across the surface in much the same manner as a tool is fed across the surface on a planer or shaper. Another type is the vertical surface grinder with a cup-shaped wheel working in much the same manner as an end mill on a vertical milling machine.

8 In doing work on lathes or milling machines, it is comparatively easy to reproduce several pieces to the same dimensions by adjusting the machine to a size. This is possible because the reducing member, which is the turning tool, will resist wear for a considerable length of time without making any difference in the size of the work.

With grinding machinery this is more difficult since the reducing member is constantly wearing away at a rapid rate. For very close work it is necessary to readjust the machine for every piece to be ground, which of course requires skill and time.

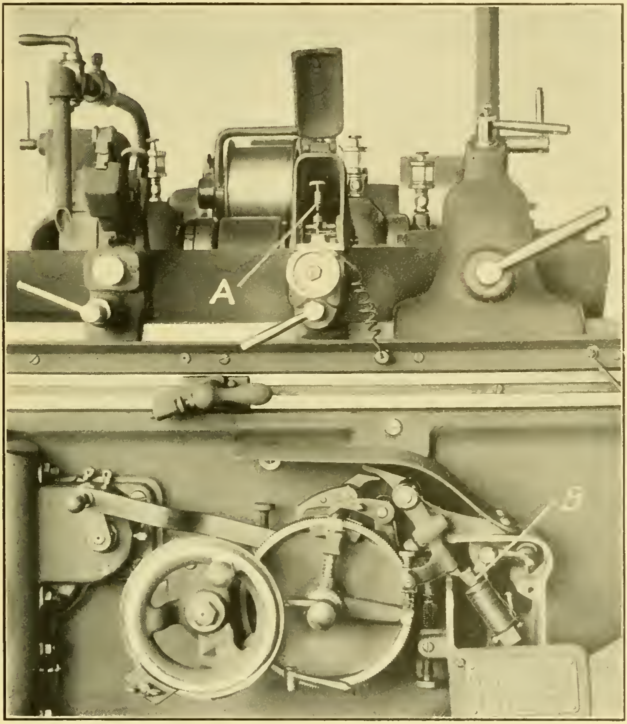

Fig. 1 View showing Device (at A) for Cylindrical Grinder, and Magnet (at B) through the Operation of which the Feed is Controlled

9 The devices shown in Fig. 1 are of such construction that they control the size of the work, no matter how much the reducing member wears way. When the work has reached the desired size, which can be predetermined by suitable adjustments, the machine will auto-

matically throw out the feed and new pieces can be put in, one after another, and these will be automatically ground to practically the same diameter, say within one-quarter of a thousandth of an inch.

10 This result is brought about by controlling the feed of the reducing member electrically. The mechanism of the controlling device is shown in Fig. 2. The lever *A* carries a smooth-pointed diamond which bears against the work *W* at *a* and at its other end is the point *b* for electrical contact. There is a second lever *C* with contact points at *c*, and a contact point *d* is attached to the frame. As the diameter of the work is reduced the long arm of lever *A* drops until point *b* touches the contact point at *c*, which, through an electrical connection changes the feed of the wheel and causes it to move against the work at a slower rate. When the work has been reduced to size, lever *A* drops still further, carrying with it lever *C*, until an electrical connection is established between points *c* and *d* which throws out the feed.

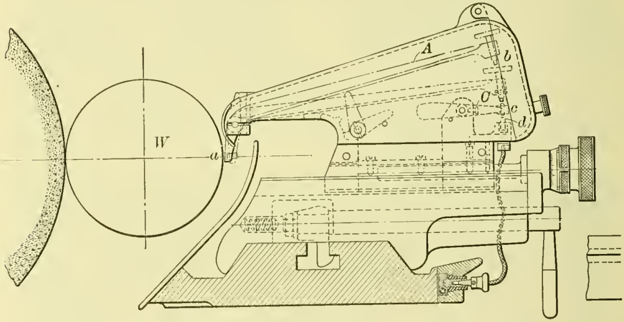

Fig. 2 View showing Mechanism of Sizing Device

11 It will easily be seen that an operator can manipulate more than one of these machines and that by their use less skill is required to get uniformity of size. In this design the size of the work is controlled by contact with the work itself, which is the preferable way, but the same results could be obtained by contact with the reducing member. This, however, would be more difficult because of the coarseness of the reducing member and its ability to wear away the contact point faster than does the work.

12 Another recent device is the back rest, shown in Fig. 3. It has been found necessary to support the work as rigidly as possible

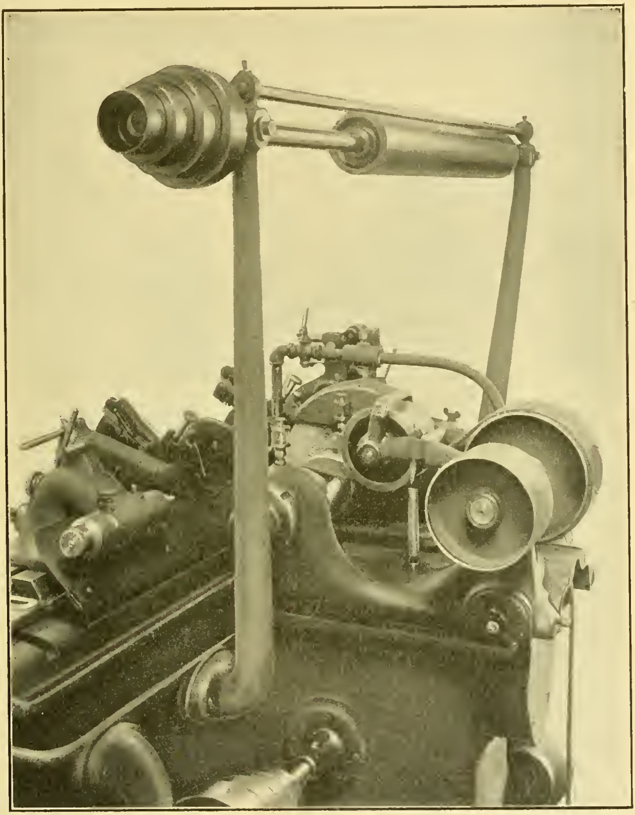

FIG. 3 VIEW SHOWING BACK REST IN PLACE; ALSO OVERHEAD DRUM, WHICH IS MADE AN INTEGRAL PART OF THE MACHINE

throughout its length, but as the work is constantly being reduced in diameter, the back rest must be kept in contact with the work either by hand or automatically, and hand adjustment requires considerable skill. In the device shown it is accomplished automatically, the back rest advancing at exactly the same rate that the diameter of the work is reduced by the wheel; and as it advances, the back rest member is locked solid, making it impossible to spring it by the wheel pressing against it when traveling across.

13 This view also shows the overhead drum, which is made an integral part of the machine. The main drive for the machine is by single belt to a short shaft at the base, from which the drives for the wheel and the drum are belted. This arrangement avoids a complicated overhead countershaft and enables the operator to change the speeds and manipulate the various mechanisms with ease.

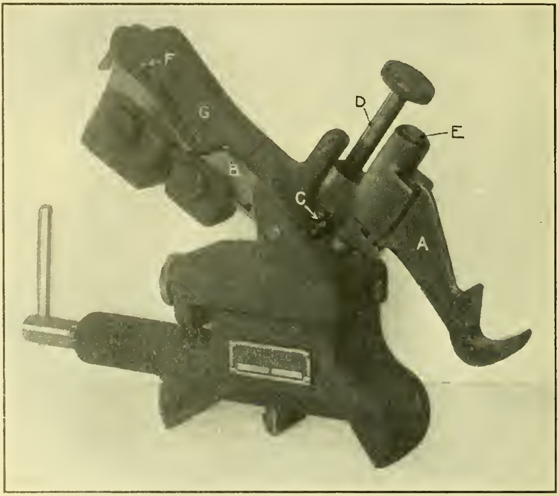

Fig. 4 Back Rest, Designed to Follow the Work as it Reduces in Diameter and to Lock Automatically against the Pressure of the Wheel

14 The operation of the back rest will be understood from Fig. 4. The arm *A* which supports the work is held in contact with the work by means of the weighted lever *B*, fulcrumed at *C*, in the frame

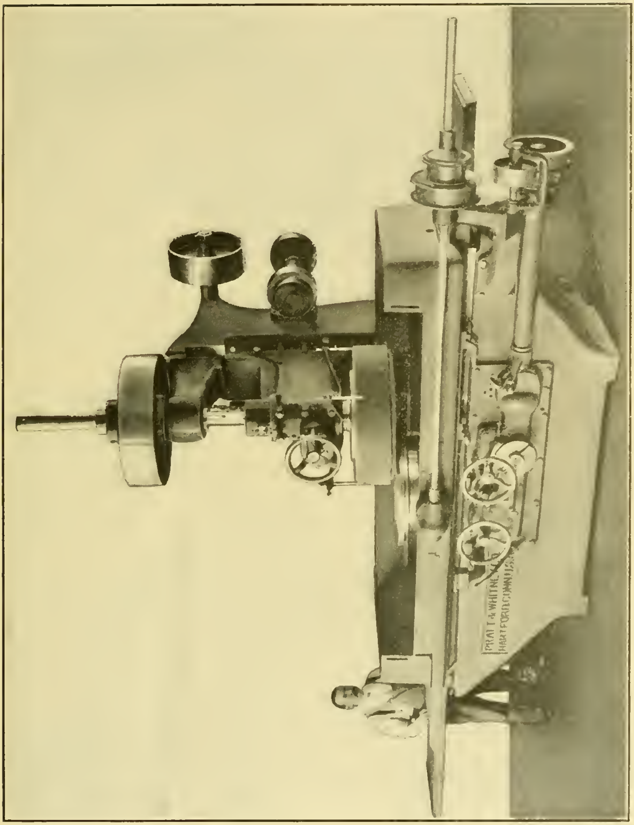

FIG. 5 SURFACE GRINDER, 25 IN. BY 60 IN., 30-IN. WHEEL; DRIVEN BY A 40-H.P. MOTOR

against the adjusting screw *D* at point C and causes the arm to slide in an upward direction on pin *E*. As lever *B* is depressed a roller *F* travels downward into the V-shaped space formed by the upper surface of lever *B* and the lower surface of the casting *G*, this roller preventing any upward movement of the lever and consequently any movement of the back rest away from the work.

15 As said before, surface grinders have usually been made with the wheel grinding on its periphery and in some instances it may be necessary to continue to do work on this principle, as grooves and irregular shapes sometimes have to be ground and the thinness of the wheel makes it possible to get into narrow places; but when flat surfaces are wanted, the cup-shaped wheel has taken a foremost place in grinding. The wheel covers the whole width of the work at once and water is forced through the center of the spindle, centrifugal force throwing the water outward and compelling it to pass between the work and the wheel. It is astonishing with what rapidity work can be reduced to a flat surface under this process.

16 This method of grinding would never have been successful if it had not been for the advancement in wheel making. The wheel problem in connection with the machine has been most difficult. It has been found very essential to select the right kind of wheel for different classes of work and for different materials. For grinding steel, either hardened or soft, corundum wheels have proved the best and for grinding cast iron the carborundum wheel has proved the best. The different degrees of hardness must be taken into consideration when the width of the surfaces to be ground varies.

17 The makers have decided to place on the market a much larger machine of this type than they have made before, shown in Fig. 5. This machine has a table stroke of 6 ft., and can grind a piece 6 ft. long and about 25 in. wide. It can also grind circular rings and disc surfaces up to 30 in. in diameter. The wheel has a diameter of 30 in. and the whole machine is driven from a single belt by a 40-h.p. motor. As this machine has just recently been built, its capability is not fully known, but for work that has already been tried it shows very encouraging results. For such work as grinding guide bars, slide valves and link motions for locomotives, large stamping dies such as are used in electric works, facing automobile cylinders and automobile engine frames, I believe it will show its superiority over any other method by several hundred per cent. In one of the trials a surface of cast iron, 6 ft. long and 20 in. wide was reduced in thickness 0.01 in. in five minutes, leaving an excellent finish and an exact

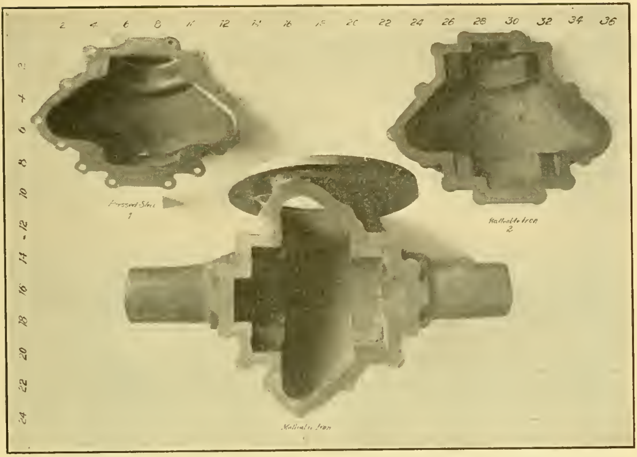

FIG. 6 EXAMPLES OF GRINDING: NO. 1, PRESSED STEEL, 15 PER HOUR; NO. 2, MALLEABLE IRON, 15 PER HOUR; NO. 3, MALLEABLE IRON, 12 PER HOUR

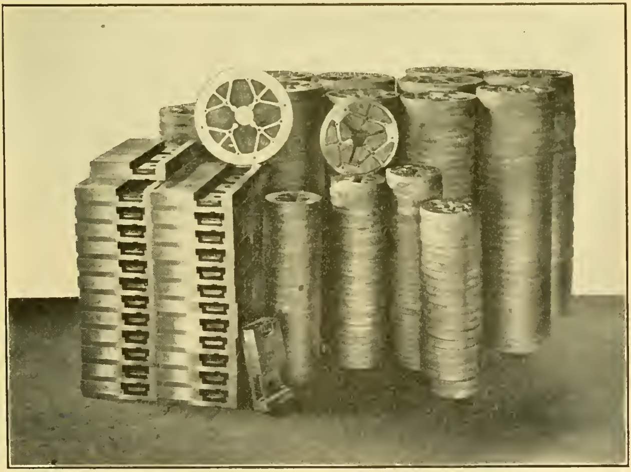

FIG. 7 EXAMPLES OF GRINDING: CHUCK PLATES, GROUND BOTH SIDES, 6-IN. 20 PER HOUR; 9-IN. 15 PER HOUR; 12-IN. 10 PER HOUR; VISES, GROUND ON TWO EDGES, TOP AND ONE CLEANED ONLY, 20 PER HOUR

flatness. In fact when tested no point in the surface showed out of true more than 0.0005 in. In grinding steel this type of surface grinder produces chips that look very much like metallic wool, which seems to indicate that when a cupped wheel passes over the work the chips are made by the outer edge of the wheel in the same manner as chips produced by the outer edge of an end milling cutter . If the chips were made underneath the broad contact surface of the wheel there would not be room for them to curl up in the small places which are left between each cutting particle of the grinding wheel. The large surface in contact with the work simply smooths the surface.

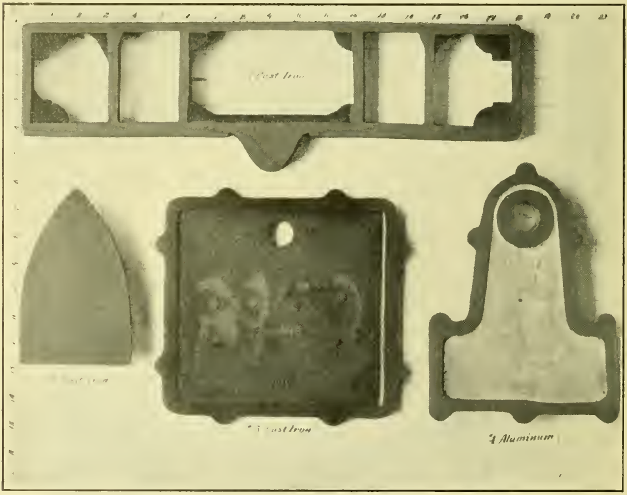

Fig. 8 Examples of Grinding: No. 1, cast iron, 15 to 20 per hour; No. 2, cast iron, 60 per hour; No. 3, cast iron, 25 per hour; No. 4, aluminum, 30 per hour

18 The table on these machines is provided with different feeds. It is difficult to make an exact rule as to what feeds to use for different materials, but the operator can determine this by running the machine a few minutes. The difficulty lies in the fact that wheels supposed to be made of the same specifications, vary considerably

and consequently the feed has to be regulated not only to suit the material being ground but also to suit the cutting ability of the wheel to be used. At the present time it is safe to say that grinding machinery is fully developed to the cutting capacity of the wheels and there will probably not be any essential changes until the grinding wheels have reached a higher development.

19 In Figs. 6 to 9 several photographs are shown of work which has been ground on vertical cupped-wheel machines. In some instances such as in the production of small gun parts, like hammers and triggers, the work has been done from fifteen to twenty times faster than it can be milled and it has a smoother and more accurate surface. This is especially true where the surfaces are not too wide.

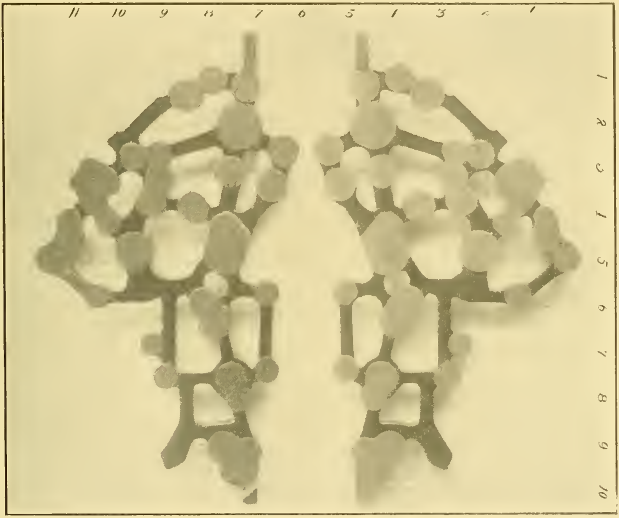

Fig. 9 Example of Grinding: Adding Machine Frame, Cast Iron, 15 per hour

20 To give an idea of the capacity of a grinding machine having a cupped wheel for grinding flat surfaces, compared with a grinding machine having a wheel grinding on its periphery and working on the principle of a planer, it is worth while to note the following:

21 The traversing speed of the work or the work table can be assumed to be the same. If a piece is 6 in. long and 3 in. wide, the machine grinding on its periphery will take about 48 strokes to cover the surface, assuming $\frac{1}{16}$-in. feed for each stroke. The cupped-wheel machine will do the same amount of work with one stroke or in about $\frac{1}{24}$ the time. These proportions are essentially true on hardened steel or on any kind of work where a nice finish is required.

GENERAL NOTES

AMERICAN INSTITUTE OF MINING ENGINEERS

A meeting of the American Institute of Mining Engineers was held in the Canal Zone, Central America, November 1 to 8. About 125 members and guests of the Institute sailed from New York October 21 to attend the meeting. Stops were made en route at Havana, Cuba, for one day, and at Kingston, Jamaica, for two days.

At Havana the party was received at the Palace by President José Miguel Gomez. Each member was individually presented to the President, who expressed the pleasure it afforded him to meet such a distinguished gathering. The party was taken around the city and suburbs in automobiles and carriages and visited many historic places. Morro Castle, in particular, proved intensely interesting.

At Kingston, Jamaica, special trains and carriages were provided, to visit Constant Spring, Castleton Gardens, Bog Walk and Spanish Town.

The eight days in the Canal Zone were devoted to excursions to various points along the line of the Canal, to inspect engineering features of the undertaking.

Sessions for technical discussion were held on the steamer on the afternoons of Oct. 24, 27 and 28. The smooth sea and pleasant weather permitted these sessions to be held on deck. On October 24 and 27 the topic of Mine Fires was discussed with papers on the Summit Hill Mine-Fire, by W. S. Lathrop; Mine Fire at the Calumet and Hecla Mine, No. 8 Shaft, by S. D. Warriner, Mem. Am.Soc.M.E.; Fire in the Big Lick Stope, Lykens Valley and Williamstown Colliery, by R. V. Norris, Mem.Am.Soc.M.E.; Fire in the Monarch Mine, near Rock Springs, Wy., by S. A. Taylor; Fire in the Anaconda Mine, Butte, Mont., by David W. Brunton, and in the Leonard Mine, Butte, Mont., by Chas. W. Goodale; Mine-Fire in the Luke Fidler Colliery, Shamokin, Pa., by R. V. Norris, Mem.Am.Soc.M.E.; Four Fires at the Vulcan Mine, Vulcan, Mich., by William Kelly; Results of the Recent Explosion in the Esperanza Mine, Coahuila, Mex., by Edw. W. Parker; Fire in the Kimberley Mine, South Africa, by Gardner F. Williams; Gold-Mines of the Rand, by Hennen Jennings. At subsequent sessions papers were presented on the Production of Pig Iron by the Electric Furnace in Sweden, by Prof. Joseph W. Richards; Operations in the Canal Zone, by W. L. Saunders, Mem.Am.Soc.M.E.; The Social and Economic Conditions in Panama and the Canal Zone, by John M. Sherrerd, Mem. Am.Soc.M.E.; Coal-Mining Machinery, by E. W. Parker; Diamonds of the Rand, by Gardner F. Williams; Recent Water-Power Developments in Montana, and the Uses of Electric Power in Pumping, Compressing and Hoisting, by Chas. W. Goodale; The Manufacture of Electrical Machines for Mining Plants, by David B. Rushmore, Mem.Am.Soc.M.E.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

At the monthly meeting of the American Institute of Electrical Engineers on Friday evening, November 11, in the Engineering Societies Building, a paper on Interpoles and Synchronous Converters by B. G. Lamme and F. D. Newbury, both of the Westinghouse Electric and Manufacturing Company, Pittsburg, Pa., was presented for discussion.

AMERICAN MUSEUM OF SAFETY

The American Museum of Safety was opened on Monday evening, November 21, in the Engineering Societies Building, 29 West 39th Street, New York, under the supervision of the director, Dr. W. H. Tolman. This is designed to be the headquarters of a national movement directed to the conservation of human life, the sanitation of environments, and the prevention of accidents. The exhibits are in three sections: safety, sanitation and mutuality. The first classification includes safety devices and appliances relating to generation and transmission of power; fire and explosives; electricity, building trades, decorative arts; agriculture, mining, lumbering; foods and conserves; manufacture of machines, tools and apparatus; stone and earth; textiles, transportation by land and sea, and theatrical enterprises. The second covers water, ventilation, heating, lighting, dusts, sewage and its disposal,noise lessening, alcoholism and housing; while under the third are comprised service insurance, pensions, liability and compensation, thrift and saving funds. One of the conspicuous exhibits is a model of a modern house with fire-proof roofing, new water filters for household, factory, field and laboratory use, in which the filtering medium is a hollow cylinder made of infusorial earth.

This museum is similar to those in Europe, of which thirteen have already been established.

AMERICAN SOCIETY OF CIVIL ENGINEERS

The annual meeting of the American Society of Civil Engineers will be held in the society house, 220 W. 57th St., New York, on January 18 and 19, 1911.

NATIONAL MACHINE TOOL BUILDERS ASSOCIATION

The ninth annual meeting of the National Machine Tool Builders Association was held at the Hotel Astor, New York, October 25 and 26. The first day was entirely devoted to business and to meetings of the several section committees. At the morning session, October 26, the following papers were read: Who Should Pay the Expenses of a Representative from the Factory When Sent out at Request of the Dealer to Help Close the Deal, F. L. Eberhardt, Mem. Am.Soc.M.E., and C. H. Norton. The Use of Ball or Roller Bearings in Machine Tool Construction, Henry Hess, Mem.Am.Soc.M.E.; Advertising—Large Space in a Few Papers vs. Small Space in a Number of Papers, Thomas A. Moore; Concrete vs. Wood Flooring, J. N. Heald. The afternoon session was opened with addresses on the Design and Construction of Machine Tools from the Users' Standpoint, C. K. Lassiter, Mem.Am.Soc.M.E., and John Riddell, Mem.Am.Soc.M.E. A striking commentary upon the work accomplished during the year is the increase in membership.

INTERNATIONAL CONGRESS OF REFRIGERATION

The second International Congress of Refrigeration was held at Vienna, Austria, October 5–16, 1910, and had a large attendance of Americans who were well represented in the papers presented. Among these were, The Relation of Micro-Organisms to Low Temperatures, Edwin F. Smith; New and Improved Methods in Manufacturing Ice, Van Rensselaer H. Greene; Investigations as to the Efficiency of Ammonia Compressors when Running under Dry and Wet System; Conditions of Acceptance, Various Tests of Materials and Parts entering into the Construction of Refrigerating Apparatus, Peter Neff; New Arrangements and Improvements in the Construction of Apparatus for Refrigeration, F. E. Mathews; Transportation of Perishable Freight in America, E. F. McPike. While the meeting place of the third congress had not yet been decided, an invitation to hold it in the United States has been extended to the organization by President Taft and was warmly seconded by the Americans present.

INTERNATIONAL CONGRESS OF MINING, METALLURGY AND PRACTICAL GEOLOGY

An International Congress devoted to Mining, Metallurgy and Geology was held at Dusseldorf, Germany, June 20 to 24, and was attended by about 1500 engineers, of whom, however, less than a dozen were from North America. The arrangements for the Congress were made by a committee representing the principal German iron and steel manufacturers in the lower Rhine district, of which Dusseldorf is a principal center, the chief responsibility being carried by Dr. Ing. H. C. Emil Schroedter, Secretary of the Verein Deutscher Eisenhuttenleute, the great German society of iron and steel metallurgists.

A long list of papers was prepared for the Congress dealing with the latest practice in iron and steel metallurgy, mining and practical geology and the machinery used in mining and in steel production. In order to cope with this varied field, the Congress met in four different sections for the presentation and discussion of the papers in these several lines of work. The technical sessions of the Congress took place on Monday, June 20 and Tuesday, June 21. While the bulk of the papers read were by German engineers, there were also important papers contributed from the United States and Canada and from England, France and other European countries outside of Germany. The complete papers and discussions at the Congress are to be published in a bound volume at an early day.

The remainder of the time was devoted to excursions to iron and steel works, mines, etc., in the Dusseldorf district and to enjoyment of the lavish entertainment provided for the visitors by the city of Dusseldorf. Over 30 of the important iron and steel works, machine shops and mines in the vicinity of Dusseldorf were opened to inspection, and the delegates to the Congress, divided into parties of convenient size, spent Wednesday and Thursday in visits to these different establishments.

On Tuesday evening the visitors were entertained at a dinner given by the city of Dusseldorf in the Tonhalle, or Municipal Concert Hall. On Wednesday evening they were taken on a steamboat excursion on the Rhine concluding with a general illumination of the city's waterfront and display of fireworks, with Count Zeppelin of dirigible balloon fame as the guest of honor. On Thursday the entire party assembled at Essen, where the concluding session was held in the hall of the Rhenish-Westphalia coal syndicate. Addresses were made by delegates from each country participating in the Congress and it was stated that a permanent organization had been formed which will arrange for future sessions of the Congress, the next one to be held in London in 1915 by invitation of the delegates from Great Britain. After adjournment the delegates were entertained by the city of Essen, at a dinner and entertainment in the municipal concert hall and garden. On Friday a large number of the delegates were taken on an excursion to Brussels, where the Exposition was visited.

The Society was represented at the Congress by Vice-President Charles Whiting Baker of New York, Editor of Engineering News.

NATIONAL SOCIETY FOR THE PROMOTION OF INDUSTRIAL EDUCATION

The fourth annual convention of the National Society for the Promotion of Industrial Education was held in Boston, November 17-19, 1910. Thursday was occupied with two sessions, one in the morning on the subjects, Demands and Opportunities for Girls in Trades and Stores, with addresses by Dr. Susan M. Kingsbury, D. S. Edwards, Mrs. Lucinda W. Prince and others; and one in the afternoon on the Training of Teachers for Girls' Trade Schools, with Mrs. Mary S. Woolman, Sarah Louise Arnold, Florence M. Marshall, as the speakers. On Thursday evening a public banquet was given in the Hotel Somerset and a welcome extended by the Lieutenant Governor of Massachusetts and by the Mayor of Boston. Speeches were also made by Frederick A. Delano, Frederick P. Fish, Chas. H. Winslow and Prof. Chas. R. Richards, Mem.Am.Soc.M.E., and President of the National Society for the Promotion of Industrial Education.

At the sessions of Friday, Apprenticeship and Corporation Schools were considered in the morning, Magnus W. Alexander, Mem.Am.Soc.M.E., acting as chairman, with addresses by Tracy Lyon, Mem.Am.Soc.M.E., F.W. Thomas, Samuel F. Hubbard, George G. Cotton, Mem.Am.Soc.M.E., and G. M. Basford, Mem.Am.Soc.M.E. In the afternoon addresses on the subject of Part Time and Evening Schools were made by W. B. Hunter, Adelbert L. Safford, Frank B. Dyer, Stratton D. Brooks and C. A. Prosser. Dr. George Kezschensteiner, Superintendent of Schools in Munich, delivered a lecture on Friday evening on Continuation Schools of Germany. At the concluding professional session on Saturday, the Social Meaning of Industrial Education was considered, with T. N. Carver, Chas. H. Winslow and others as the speakers.

The officers for the ensuing year, elected at the annual business meeting, are President, Chas. R. Richards, Mem.Am.Soc.M.E., Director of Cooper Union; Vice-President, J. W. Lieb, Jr., Mem.Am.Soc.M.E., New York Edison Co.; Treasurer, Frederic B. Pratt, Pratt Institute, Brooklyn; Secretarv. Edward H. Reisner, Columbia University.

NEW YORK ELECTRICAL SOCEITY

The New York Electrical Society is signalizing the 40th year of its existence by a series of lectures on electricity and applied science. The program comprises addresses on Animated Photography in Natural Colors, by Gilbert H. Aymar; The Effect of the Telephone on Modern Industrial and Social Life, by Herbert N. Casson; The Catskill Water Supply, by Hon. Chas. N. Chadwick; Electricity at the Panama Canal, by David B. Rushmore, Mem.Am.Soc.M.E; Hydro-Electric Development in Mexico, by F. O. Blackwell; The Rapid Transit Problem of New York City, by H. St. Clair Putnam; Wave Motion by Electricity and Other Energy, by Dr. Chas. P. Steinmetz, Mem.Am.Soc.M.E.; The Physics of Light Sources, by Dr. Edward P. Hyde; The Relation of the Modern Incandescent Lamp to the Central Station, by S. E. Doane. All of these lectures, with the exception of that by Mr. Blackwell which will be delivered in the Hispanic Society Building, will be given in the Engineering Societies Building, and a card of invitation can be secured on application by any member of The American Society of Mechanical Engineers from the Secretary, Mr. George H. Guy.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS

The eighteenth general meeting of the Society of Naval Architects and Marine Engineers was held in the Engineering Societies Building, New York, November 17 and 18. Among the papers read were: Notes on the Armaments of Battle Ships, Sir William White; The Evolution of Screw Propulsion in the United States, Part 2, Charles H. Cramp; The History and Economic Value of Canals with Special Reference to the Cape Cod Canal, Jacob W. Miller; Coaling War Ships; Notes of Progress, Spencer Miller; Floating Dry Docks in the United States; Relative Value of Wood and Steel for their Construction, William T. Donnelly; Our Constitutional Shipping Policy and the Compact for its Establishment, William W. Bates; An Analysis of Tests of Watertight Bulkheads, with Practical Rules and Tables for their Construction, William Hovgaard; Comparative Results in Steam and Coal Consumption with Turbines, Reciprocating Engines and a Combination of the Two, on the Steam Yacht Vanadis, Clinton H. Grane; The Gyroscope for Marine Purposes, Elmer A. Sperry; New Propelling Machinery of the S. S. Creole, John F. Metten; Some Suggestions for Reducing Loss by Fire on Shipboard, Samuel D. McComb; Two Marine Installations of Producer Gas Power, Charles B. Page.

PERSONALS

Alfred R. Bench, formerly connected with the W. H. Zimmerman Co., Chicago, Ill., has become associated with the Taylor Iron & Steel Co., High Bridge, N. J.

Joseph Breslove has entered the employ of the Nivison-Weiskopf Co. Until recently he was associated with the Westinghouse Machine Co., East Pittsburg, Pa.

Edwin H. Brown has formed a partnership with Edwin H. Hewitt under the firm name of Hewitt & Brown, Architects and Engineers, with offices in Minneapolis, Minn. Mr. Brown was until recently identified with the Cadwell & Brown Co., Minneapolis, Minn.

Thurlow E. Coon and John DeVisser have formed a partnership, under the firm name of Coon-DeVisser Co., with offices in Detroit, Mich. They will conduct a general power plant business.

William T. English, formerly president of the English & Flett Co., Inc. Boston, Mass., is now president of the Walworth-English-Flett Co., of the same city, a consolidation of the company with the Walworth Construction & Supply Co.

A. E. Greene has resigned his position as chief engineer of the New Departure Manufacturing Co., Bristol, Conn., and has opened an office in Hartford, Conn.

Charles A. Howard has become identified with Gunn, Richards & Co., New York as mechanical engineer. He was formerly manager of the turbine department of E. W. Bliss Co., Brooklyn, N. Y.

R. M. Hvid has accepted a position with the Advance Thresher Co., Battle Creek, Mich., as engineer in charge of construction.

L. L. Johnson has resigned his position as gas engineer of the electrical department of the Southern Pacific Co., San Francisco, Cal., to take up consulting engineering relative to gas power and fuel plants, with office in Indianapolis, Ind.

W. A. Kennedy, formerly instructor of mechanical drawing, Brown University, Providence, R. I., has become testing engineer of the General Fire Extinguisher Co., of the same city.

Gompei Kuwada has become associated with the Osaka Gas Co., Osaka, Japan. He was formerly superintendent of machine shops, Kawasaki Dock Yard Co., Kobe, Japan.

Kenneth B. Millett has entered the employ of the Newburgh Ice Machine & Engine Co., Newburgh, N. Y. Until recently, Mr. Millett was factory superintendent of the Protal Co., Bridgeport, Conn.

J. E. Muhlfeld, formerly general superintendent of motive power of the B. & O. R. R., Baltimore, Md., has been appointed vice-president and general manager of the Kansas City Southern Railway, Kansas City, Mo.

C. D. Pettis, formerly associated with the Hewitt Manufacturing Co., Chicago, Ill., has accepted a position with the American Brake Shoe & Foundry Co. of the same city.

Hollis P. Porter, recently president and manager of the Schlafli & Porter Co., Houston, Tex., has accepted a position with the Cerro de Pasco Mining Co., Peru, S. A., as chief engineer of power.

A. J. Purinton has become associated with the St. Joseph Railway, Light, Heat & Power Co., St. Joseph, Mo., in the capacity of general superintendent. He was formerly manager for receiver, Toldeo & Chicago Interurban Railway Co., Kendallville, Ind.

Paul S. Rattle has recently taken charge of the pump and compressor department of the Mine & Smelter Supply Co., Denver, Colo. Mr. Rattle was formerly associated with the Hicks Locomotive & Car Works of the same city.

David H. Ray was appointed chief engineer of the Bureau of Buildings of the Borough of Manhattan. He was formerly associated with the faculty of the College of the City of New York.

William A. Richards has been placed in charge of the machine shops of the University High School, University of Chicago, Chicago, Ill., in addition to the forge and foundry which he has had for the last two years.

Wilbur N. Sar Vant has accepted the position of assistant chief engineer of the Standard Turpentine Co. of Florida, Jacksonville, Fla.

Ernest B. Sellew, formerly chief draftsman of Potter & Johnston Co., Pawtucket, R. I., has been appointed president and manager of the Sellew Machine Tool Co. of the same city.

Charles P. Smith formerly associated with the General Electric Co., Lynn, Mass., has become identified with the Lower Pacific Mills, Lawrence, Mass.

William S. Twining has become identified with Ford, Bacon & Davis, New York. He was until recently chief engineer of the Philadelphia Rapid Transit Co., Philadelphia, Pa.

James A. White, formerly connected with the General Electric Co., Lynn, Mass., has accepted a position with the Worcester Pressed Steel Co., Worcester, Mass.

Alan G. Williams has been appointed general foreman of the Buffalo Shops of the Pennsylvania R. R. Co. He was formerly night enginehouse foreman of the Co. at Oil City, Pa.

ACCESSIONS TO THE LIBRARY

This list includes only accessions to the library of this Society, included in the Engineering Library. Lists of accessions to the libraries of the A. I. E. E. and A. I. M. E. can be secured on request from Calvin W. Rice, Secretary, Am. Soc. M. E.

AMERICAN STREET AND INTERURBAN RAILWAY ACCOUNTANTS ASSOCIATION. *1910.* Papers read at Convention 1910. Gift of American Street and Interurban Railway Association.

AMERICAN STREET AND INTERURBAN RAILWAY TRANSPORTATION AND TRAFFIC ASSOCIATION. Papers read at Convention 1910. *1910.* Gift of American Street and Interurban Railway Association.

ASOCIACION DE INGENIEROS Y ARQUITECTOS DEL URUGUAY. Revista. Ano. 11–1908. *Montevideo, 1908.*

CAMBRIDGE (MASS.) WATER BOARD. Annual Report 1909–1910. *Cambridge, 1910.*

DECIMAL ASSOCIATION. Report of Debate on the Metric System in the House of Representatives of the Commonwealth of Australia on August 4, 1910. *London.*

FRANKLIN INSTITUTE. Index to the Journal. 1826–1885. *Philadelphia, 1890.* Gift of H. R. Towne.

INDICATOR HANDBOOK. Ed. 4. By C. N. Pickworth, *New York, 1910.* Gift of the author.

MEMORIALS OF THE LINEAGE, EARLY LIFE, EDUCATION AND DEVELOPMENT OF THE GENIUS OF JAMES WATT. By George Williamson. 1856. Gift of George Tangye, Esquire.

METHODS OF PROTECTING EMBANKMENTS AGAINST CURRENTS AND RESTORING THEM WHEN WASHED OUT. Report of committee.

MODERN EQUIPMENT OF COAL MINES. By W. C. Mountain. Paper read before the Indian Section of the Institution of Mechanical Engineers, January 26, 1910.

MONOGRAPHIE SUR L'ETAT ACTUEL DE L'INDUSTRIE DU FROID EN FRANCE. Congrès de Vienne, October 1910. *Paris, 1910.* Gift of J. C. Bertsch.

NEW ORLEANS. Sewerage and Water Board. 21st Semi-Annual Report. *1910.* Gift of the board.

WORLD CORPORATION. By K. C. Gillette. *Boston, New England News Co., 1910.* Gift of the author.

EXCHANGES

AMERICAN STREET AND INTERURBAN RAILWAY ENGINEERING ASSOCIATION. Papers read at Convention, 1910.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA. Proceedings. vol. 25. *Pittsburgh, 1909.*

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA. Charter, By-Laws, List of Members, September 15, 1910. *Pittsburgh, 1910.*

INSTITUTION OF CIVIL ENGINEERS OF IRELAND. Transactions. vol. 36. *Dublin, 1910.*

THE TRANSIT. vol. 14, 15. *Iowa City, 1909, 1910.*

GIFT OF MR. J. C. BERTSCH

APERÇU SOMMAIRE DE L'ETAT ACTUEL DE L'APPLICATION DU FROID AU COMMERCE ET À L'INDUSTRIE EN RUSSIE. *St. Petersburg, 1910.*

BERICHTE AN DEN ZEITEN INTERNATIONALEN KALTEKONGRESS IN WIEN 1910. *Kopenhagen, 1910.*

EIS UND KÄLTE INDUSTRIE vol. 12, no. 10. *October 1910.*

CONGRÈS INTERNATIONAL DES INDUSTRIES FRIGORIFIQUES, VIENNE, 6–11. Octobre 1910. Notice sur l'industrie frigorifique des viandes dans la Republique Argentine. *Buenos Ayres, 1910.*

L'INDUSTRIE FRIGORIFIQUE. April 1910. *Paris, 1910.*

INTERNATIONALEN KÄLTEKONGRESSES. *Wien, 1910.* Bulletin no. 5–7, 1910.

KÄLTE INDUSTRIE, vol. 7. number 10. October 1910. *Hamburg, 1910.*

KÜHLANLAGEN DER K. K. REICHSHAUPT AND RESIDENZSTADT WIEN.

TRANSPORTS DES DENREES PERISSABLES SUR LE RESEAU FERRE DE L'EMPIRE RUSSE. Par D. de Golovnine. *Moscow, 1910.*

ÜBER DIE OEKONOMIK UND STATISTIK DER WARMEWIRTSCHAFT BEI DER KUNSTLICHEN KÄLTEERZEUGUNG. *St. Petersburg, 1910.*

ZEITSCHRIFT FÜR EIS UND KÄLTE INDUSTRIE vol. 3, no. 4, October 1910. *Vienna, 1910.*

ZEITSCHRIFT FÜR DIE GESAMMTE KÄLTE INDUSTRIE, vol. 17, number 10. *Munich, 1910.*

INTERNATIONAL REFRIGERATION CONGRESS (2D), VIENNA 1910

ABATTOIRS AND MARKETS OF PRAGUE. By Em. Stehlik.

ALIMENTATION DES NATIONS. By A. de Wendrich.

ANWENDUNG DER KÄLTE BEI DER ERZEUGUNG VON AZOFARBSTOFFEN. By Daniel Rittermann.

ANWENDUNG DER KÄLTE BEI DER BEHANDLUNG VON HAUTKRANKHEITEN. By Eduard Schiff.

DIE ANWENDUNG DER KÄLTE IN DER CHIRURGIE. By Hans Lorenz.

DIE ANWENDUNG DER KÄLTE IN DER MARGARINE-FABRIKATION. By F. Barth.

ANWENDUNG KÜNSTLICHER KÄLTE IN HÜTTENWERKEN. By R. C. A. Banfield.

ANWENDUNG UND EINRICHTUNG VON OZONAPPARATEN IN KÜHLRAÜMEN. By Alois Schwarz.

APPLICATION OF ARTIFICIAL COLD IN THE MANUFACTURE OF PARRAFFIN IN AUSTRIA-HUNGARY. By Philipp Porges.

APPLICATION OF ARTIFICIAL COLD IN PLANT CULTIVATION. By P. de Vries.

APPLICATION OF COLD IN OIL-GAS PRODUCER PLANTS. By J. Reidrer.

APPLICATION OF LOW TEMPERATURES TO THE CURING AND STORAGE OF CHEDDAR CHEESE. By. S. M. Babcock.

Application of Refrigeration to the Glue and Gelatine Industry. By Paul Cavalier.

Application of Refrigeration to the Retarding of Plants and the Preservation of Flowers. By L. C. Corbett.

Application of Refrigeration to the Raw Materials of the Perfumery Industry. By Paul Jeancard.

Arrangement and Management of Open-Air Artificial Ice Rinks. By E. Engelmann.

Artificial Production of Low Temperature in the Biological Experimenting Establishment. By H. Przibram.

Bedeutung und Anwendung niedriger Temperaturen in der Textilindustrie. By F. Erban.

Beer Transport on Railways. By Alois Holitsch.

Changes in the Physical and Morphological Conditions of Food Stuffs (meat fish and milk) by Cold. By Dr. Butzler.

Cold Technics in Connection with the Paraffin Industry in Holland and the Dutch Colonies. By E. S. Kerkhoven.

Cold Without Fuel, and its Consequences. By Ch. Tellier.

Conditions of Acceptance, Various Tests (resistance, stanchness, etc.) of the Materials and Parts Entering into the Construction of Refrigerating Apparatus. By Peter Neff.

Effect of Cold Storage upon the Bacteriological and Chemical Changes in Milk and Butter. By Chas. E. Marshall.

Effect of Low Temperatures on the Life Process of Fruits and on the Rate of Fermentation of Cider. By H. C. Gore.

Einfuhr und Ausfuhr von Fleisch in den Verschiedenen Ländern und Beantwortung der Frage: ist für die Niederlande die Einfuhr von gefrorenem und gekühltem Fleisch aus dem Auslande Wünschenswert. By F. B. Lohnis and D. A. de Jong.

Elektrischen Fernthermometer. By J. Rautenkrantz.

Experiments on Dry and Wet Compressor Procedure of Condensing Cold Steam Machines. By Adolph Tegetmayer.

La Fabrication de la Glace. By Mr. Sandras.

Fabrikationsprozesse, welche zur Gewinnung von Paraffin unter verwendung von Künstlicher Kälte dienen.

Fleischfrage und Kälte-industrie. By Eugen Vamos.

Handling Ice at Ice Plants and Car Icing Stations. By H. B. Wood.

Importance of Refrigeration for Foods with Special Consideration of Milk. By Hans Messner.

Improved Method of Packing Gutted Fish for Transport and Keeping it Fresh and Sweet for a Long Time. By A. Sölling.

Influence and Application of Cold in Mercerising. By A. Kirchacker.

Installations Frigorifiques de la Ville de Prague. By Louis Cizek.

Instruction in Cold Technics in Holland. By M. de Haas.

International Refrigeration Congress, Vienna, 1910. Programme of the Commission on Transportation. By R. Bloch.

Investigations as to the Efficiency of Ammonia Compressors when Running under Dry and Wet Conditions. By T. Shipley.

Kontrolle der Kühlanlagen. By E. Jalowetz.

Kühlanlagen als Akkumulatoren für die Armeeversorgung im Felde. By H. Heiss.

Manufacture of Crystal Ice from Exhaust Steam and the Practical Results Obtained by this Process. By R. C. A. Banfield.

New and Improved Arrangements in the Installation and Operation of Ice Factories. By Van R. H. Green.

New Arrangements and Improvements in the Construction of Apparatus for Refrigeration, Results of Experiments Thereon. By F. E. Matthews.

Die Organization der Kälte-Vereine. By Alois Schwarz.

Possibility of Employing Turbo-Blowers as Cooling Machine Condensers. By Hans Lorenz.

Precooling of Fruit in the United States. By S. J. Dennis.

Refrigerating Plants on Ships. By H. Wagner.

Refrigeration and Ventilation of Inhabited Places. By H. Torrance, Jr.

Relation of Micro-Organisms to Low Temperatures. By E. F. Smith.

Shaft Sinking by Freezing Process. By Franz Drobniak.

Superheated Vapors Employed in Refrigeration. By J. E. Siebel.

Statistics of Refrigerated Transportation. By M. A. de Wendrich.

Transportation of Perishable Freight in America. By E. F. McPike.

Untersuchungen über die Konservierung von Pferdefleisch Mittels Kälte und dessen Verwendung zu Nahrungszwecken.

Use of Cold in the Pharmaceutic Products Industry. By E. Tassilly.

Use of Cold for Destroying Tobacco Worm. By G. Poock.

Versicherungswesen in seinem Zusammenhange mit der Kälteindustrie. By Emil Regen.

Warmth Conduction of Pulverous Bodies and a New System of Warmth Isolation Based Thereon. By M. V. Smoluchowski.

Was Soll man unter dem Oekonomischen Wirkungsgrad einer Kältemaschine Verstehen. By A By A. Satkewitsch. *Berlin, 1910.*

Welche Anspruche Sind an einen guten Kühlwagen zu Stellen.

Zweckmassige Kühlanlagen an Modern Eingerichteten Schlachthofen. By Mr. Dohmann.

TRADE CATALOGUES

Bristol Co., *Waterbury, Conn.* Bull. No. 126, Class II recording thermometers, 314; Bull. No. 128, Round form, class II, 8-inch, recording thermometers, 3 pp.; Bull. No. 129, Thermometer, Thermostats, classes I, II and III, 7 pp.; Bull. No. 135, Recording shunt ammeters for all ranges of direct current, 7 pp.; Bull. No. 141, Round form recording pressure gages, 11 pp.; Bull. 145, class II indicating thermometers, 1 pp.; Bull. No. 146, Long-distance recording tachometers, 1 p.; Bull. No. 147, Bristol-Durand radii averaging instrument, 3 pp.

Buff & Buff Mfg. Co., *Boston, Mass.* High grade engineering, surveying, and mining instruments, 117 pp.

Builders Iron Foundry, *Providence, R. I.* Venturi hot water meter for boiler feed, etc., 16 pp.

CALDWELL ECONOMY CO., *New York.* Westover multiple record CO_2 recorder, 4 pp.

CHAMPION RIVET CO., *Cleveland, O.* Boiler, ship, and structural rivets, 83 pp.

C. & G. COOPER CO., *Mount Vernon, O.* Seventy-five years of engine building; a history of the Cooper works and their products, 50 pp.

HESS-BRIGHT MFG. CO., *Phila., Pa.* Ball bearings and their correct use, 5 pp.

INDUSTRIAL INSTRUMENT CO., *Foxboro, Mass.* Foxboro Recorder vol. 4, No. 2, 14 pp.

H. W. JOHNS-MANVILLE CO., *Cleveland, O.* J.-M. Packing Expert, October 1910, 4 pp.; J.-M. Roofing Salesman, November 1910, 8 pp.

J. GEO. LEYNER ENGRG., WORKS CO., *Littleton, Colo.* Bull. No. 1024, Leyner stoppers, dry pattern for solid steel, 10 pp.

NATIONAL ELECTRIC LAMP ASSOC., *Cleveland, O.* Bull. No. 13, Mazda multiple lamps, 19 pp.; Bull. No. 14, Hylo-economical, turn-down electric lamps, 11 pp.

NORTH WESTERN EXPANDED METAL CO., *Chicago, Ill.* Designing data II for reinforced concrete, 46 pp.

OSGOOD SCALE CO., *Birmingham, N. Y.* Standard scales of all styles, 94 pp.

STANDARD UNDERGROUND CABLE CO., *Pittsburg, Pa.* Handbook of price lists, 228 pp.; Leaflets on wires and cables, 26 pp.; Varnished cloth insulated wire and cable, 12 pp.; Open air cable terminals, 8 pp.; Colonial copper clad wire, 32 pp.; Joints and jointing material, 20 pp.

TERRY STEAM TURBINE CO., *Hartford, Conn.* Bull. No. 7, Three bearing type gas blower set, 7 pp.

TEXAS CO., *Houston, Texas.* What is asphalt, 8 pp.; Texaco paving filler, 16 pp.; Texaco paving cement, 15 pp.; Texaco, the road builder, 18 pp.

UNDERFEED STOKER CO. OF AMERICA, *Chicago, Ill.* Publicity Magazine, November, 1910, 15 pp.

UNITED ENGINEERING SOCIETY

ENGINEERING NEWS. Index 1905–1909. *New York, 1910.*

KELLEY'S DIRECTORY OF ENGINEERS AND IRON AND METAL TRADES. 1909. *London, 1909.*

MODERN ACHIEVEMENT. Vol. 1–10. *New York.* Gift of J. A. Coles.

MOODY'S MANUAL OF RAILROADS AND CORPORATION SECURITIES. 1910. *New York, 1910.*

NEW CENTURY REFERENCE LIBRARY. Vol. 1–8. *New York, 1910.* Gift of J. A. Coles.

SCIENCE-HISTORY OF THE UNIVERSE. Vol. 1–10. *New York, 1910.* Gift of J. A. Coles.

EMPLOYMENT BULLETIN

The Society has always considered it a special obligation and pleasant duty to be the medium of securing better positions for its members. The Secretary gives this his personal attention and is most anxious to receive requests both for positions and for men available. Notices are not repeated except upon special request. Copy for notices in this Bulletin should be received before the 12th of the month. The list of men available is made up of members of the Society and these are on file, with the names of other good men not members of the Society, who are capable of filling responsible positions. Information will be sent upon application.

POSITIONS AVAILABLE

057 Instructor in kinematics wanted in an eastern college, to give text book, lecture and drawing room course in the subject. In applying state technical education and practical experience, references and salary expected.

058 Large manufacturing company in Pennsylvania, organizing a department of engineering sales, offers opportunities in this department to three or four bright, hustling, young engineers. Accepted applicants will be required to spend a few months in drawing room and shops prior to taking up work as traveling sales engineers. Salary to commence, $800 to $1000 a year.

059 Member, engaged in inspection, investigations reports, etc., desires to communicate with one who would buy an interest in present business to which another specialty might be added.

060 Competent engineer, good draftsman and designer with experience in steam and power pump construction. Location Michigan.

MEN AVAILABLE

143 Technical graduate in mechanical engineering and manual training school,—Junior member, married,—four years' experience, engaged in special work in large industrial plant, nature to be of benefit in almost any line. Desires change of position, permanency sought.

144 Stevens graduate, 17 years experience, design, construction and management of manufacturing plants, patents, cost system, purchasing; specially interested in economics, organization and reduction of costs, from boiler room to finished product. Desires position in executive capacity, with a new business or one needing reorganizing, prefer New York City. If satisfactory would invest in the undertaking.

145 Mechanical engineer, graduate Stevens Institute of Technology; executive ability, experience in industrial engineering and factory management, design, construction and supervision of complete power plant equipment; successful commercial engineer; at present holding a managerial position, wishes to represent or become associated with a firm in New York preferred where initiative and business ability coupled with technical education will lead to executive responsibility. Best of references.

146 Member desires position as general superintendent, representative, or consulting engineer in Boston or other New England manufacturing concern, devoting all or part of time.

147 Associate Member, American, married, successful experience as machinist, tool and model maker, foreman and works manager, broad, practical experience as manufacturer of instruments of precision, tools and jigs for the rapid out-put of parts in manufacturing; over six years varied experience, building, starting new factories and selling in the Orient; open for a position in an executive capacity or superintendent. Location no object. Would travel.

148 Young engineer, Junior member, Stevens graduate, married, experience in operation end of manufacturing concerns, erection, maintenance and repairs of steel mills, decorticating, saw mill, textile, coal handling, and power plant machinery. Desires position in executive capacity with concern manufacturing machinery in these or associated lines. Location East or Middle West.

149 Sales engineer, would consider position where knowledge of machinery and mill supply trade of the United States and Canada is essential; seven years varied engineering experience; six years in selling end. Experience in correspondence and design of selling contracts.

150 Veteran engineer and sales office manager for over twenty years desires position where acquaintanceship and standing among fellow members and thorough understanding of steam specialty business will be of value in improving or putting product on market. Practical mechanic.

151 Superintendent and works manager, thoroughly capable in every department, desires change. Technical and practical education, long experience in handling men, shop accounting, special engineering, foundry and shop management. At present in charge of large plant manufacturing transmission machinery and large jobbing line.

152 New York member, twenty-five years practical experience in steam engineering, designing, contracting for installing and operating steam power and heating plants. Technical education. Desires position as engineer in charge or would associate with capitalist or company to contract for above work.

153 Graduate civil engineer with general railroad field work, construction and maintenance of way; three years in engineering department of large electrical company, two in full charge of structural department; held positions as chief draftsman in charge of all classes of work, handling complete designs of power stations, etc., structural engineer, consulting engineer or superintendent of construction.

CHANGES IN MEMBERSHIP

CHANGES OF ADDRESS

ABRAHAMS, M. Landa (Junior, 1910), 2106 Arch St., Philadelphia, Pa.

ALLEN, John Robins (1984; 1903), Prof. Mech. Engrg., 221 New Engrg. Bldg., Ann Arbor, Mich.

ANDERSON, Emanuel (Associate, 1907), 5301 Kenmore Ave., Chicago, Ill.

ARMSTEAD, Frank C. (1906), Engr. Stoker Dept., Westinghouse Mch. Co., 165 Broadway, New York, and *for mail,* 1085 E. 17th St., Brooklyn, N. Y.

BANFIELD, Frederic E., Jr. (Junior, 1909), Mech. Engr., Saco & Petee Mch. Co., and *for mail* 17 Woodward St., Newton Highlands, Mass.

BASINGER, James G. (1907), Civ. Engr., 52 Broadway, New York, and 181 Bowne Ave., Flushing, L. I., N. Y.

BEDELL, Edgar Harrington (Junior, 1910), 216 Mt. Prospect Ave., Newark, N. J.

BENCH, Alfred Rittscher (Junior, 1907), Taylor Iron & Steel Co., High Bridge, N. J.

BEVIN, Sydney (Junior, 1909), 150 W. 76th St., New York, N. Y.

BORDE, George U. (1909), Cons. Engr., 820–822 Hibernia Bldg., New Orleans La.

BRAINE Bancroft G. (1896; 1905), Engr., Rail Joint Co., 185 Madison Ave., New York, and 67 First Pl., Brooklyn, N. Y.

BRAUN, Carl F. (Junior, 1907), Pres., Braun, Williams & Russell, Inc., 503 Market St., S. E., San Francisco, Cal.

BRENNER, Wm. H. (1897), 210 Simpson St., Atlanta, Ga.

BROWN, Edwin Hacker (Junior, 1903), Member of Firm, Hewitt & Brown, 716 Fourth Ave., S., and 2303 Pleasant Ave., Minneapolis, Minn.

BROWN, Walter Ellsworth (Junior, 1910), Asst. Engr. and Supt., Penn Motor Car Co., 7510 Thomas Blvd., Pittsburg, Pa.

BRYAN, William H. (1891), Cons. Mech. and Elec. Engr., 418–419 Title Guaranty Bldg., and 5718 Vernon Ave., St. Louis, Mo.

BURGESS, A. Bradley (Junior, 1901), Engr., Standard Plunger Elev. Co., Worcester, Mass.

CARLE, Nathaniel A. (1907), Cons. and Contr. Engr., 709 Central Bldg., Seattle, Wash.

COLLIER, Wm. H. (1901; 1904), Mgr., So. Motor Wks., Nashville, Tenn.

COLWELL, James V. V. (1903), Life Member; Mgr. N. E. Dept., Heine Safety Boiler Co., Rm. 302, 201 Devonshire St., Boston, Mass., and 1765 Sedgwick Ave., New York, N. Y.

COOK, John P. (Junior, 1906), 31 Garfield Pl., Albany, N. Y.

COON, Thurlow E. (Junior, 1908), Partner, Coon-DeVisser Co., 1801 Ford Bldg., and 55 Leicester Court, Detroit, Mich.

DURANT, Aldrich (Junior, 1906), 120 E. 31st St., New York, N. Y., and 9 Lowell St., Cambridge, Mass.

ENGLISH, William T. (1902), Pres., Walworth-English-Flett Co., 100 Pearl St., Boston, and 185 W. River St., Hyde Park, Mass.

FIEUX, Ernest D. (Junior, 1907), Pres. and Treas., L. J. Wing Mfg. Co., 90 West St., New York, and *for mail,* Commonwealth Ave., Chester Hill Park, Mt. Vernon. N. Y.

GAEHR, David (1902; 1909), Contr. Engr., 950–952 Rockefeller Bldg., and 2626 E. 75th St., Cleveland, O.

GAMPER, Herman (1900), Supt., Munic, Ltg. Dept., and *for mail,* 377 W. 9th Ave., Columbus, O.

GORE, Warren W. (1908), Exper. Engr., Fairbanks, Morse Mfg. Co., and *for mail,* 911 Harrison Ave., Beloit, Wis.

GREENE, Augustine E. (1909), Mill Engr., 60 Prospect St., Hartford, Conn.

GUY, Albert Emile (1905), Mech. Engr., E. Hamilton Ave., R. F. D. 3, Trenton, N. J.

HARTER, Isaac, Jr. (Associate, 1908), Babcock & Wilcox Co., Bayonne, N. J.

HEALY, Frederick E. (1906), Mech. Engr. and Spec. Agt., Alberene Stone Co., New York, N. Y., and *for mail,* 1350 Monroe St., N. W., Washington, D. C.

HEISLER, Charles L. (1895), 323 Glenwood Blvd., Schenectady, N.Y.

HERBERT, Jack Stanley (1908), V. P. and Ch. Engr., Penn Motor Car Co., 7510 Thomas Blvd., Pittsburg, Pa.

HIGGINS, Albert W. (Associate, 1906), 106 Wenham Ave., Grand Rapids, Mich.

HOFMEYER, George August (Associate, 1905), Cons. Engr., 207 W. 24th St., and *for mail,* 145 W. 16th St., New York, N. Y.

HOLLOWAY, Thurman Welford (Junior, 1906), Internatl. Corr. Schools, Ltd., Scranton, Pa.

HOWARD, Chas. Alton (Junior, 1907), Mech. Engr., Gunn, Richards & Co., 43 Wall St., New York, N. Y.

HURD, Charles Henry (1902), Mech. and Hyd. Engr., 113 Monument Pl., Indianapolis, Ind.

HURLEY, Daniel (Junior, 1904), Watertown Arsenal, Watertown, Mass., and 42 E. Manning St., Providence, R. I.

JAQUAYS, Homer Morton (1899; 1903), Montreal Rolling Mill Co., 3106 Notre Dame St., Montreal, and *for mail,* 645 Grosvenor Ave., Westmount, P. Q., Canada.

JOHNSON, Warren (Associate, 1904), Cons. Engr., 122 Carondelet St., and 6209 Howard St., New Orleans, La.

JURGENSEN, Jess Christian (Associate, 1905), 114 Main St., Hackensack, N. J.

KENNEDY, William A. (Junior, 1908), Testing Engr., Genl. Fire Extinguisher Co., and *for mail,* 31 Forest St., Providence, R. I.

KEYES, Frederic H. (1902), 88 Broad St., Boston, Mass.

KING, W. Grant (1894; 1904), V. P. and Genl. Mgr., King Sewing Mch. Co., 90 Welland St., Buffalo, N. Y.

KUWADA, Gompei, (1900), Osaka Gas Co., Osaka, Japan.

LOUER, Lewis S. (Associate, 1900), Western Mgr., Engrg. Record, 1570 Old Colony Bldg., Chicago, Ill.

McCREERY, James Harold (Junior, 1910), 802 Atlantic Bldg., 49 Wall St., New York, N. Y., and *for mail*, 415 W. 7th St., Plainfield, N. J.

McMULLIN, Frank V. (1903), United Eng. & Fdy. Co., 2313 Farmers Bank Bldg., Pittsburg, Pa.

MacGILL, Charles Frederick (1896), 1489 Minnehaha Ave., St. Paul, Minn.

MANLEY, Sumner Marshall (Junior, 1907), M. M., Proctor & Gamble Co., and *for mail*, 3616 Jefferson St., Kansas City, Mo.

MARSHALL, Stewart McCulloch (1907; 1910), Asst. Ch. Engr., Cambria Steel Co., and *for mail*, 134 Tioga St., Johnstown, Pa.

MARTENS, Ferdinand (1885), care Dr. H. Joachim, Hofweg 13, Hamburg, Germany.

MILLETT, Kenneth Ballard (Junior, 1908), Newburgh Ice Mch. & Eng. Co., and *for mail*, P. O. Box 243, Newburgh, N. Y.

MOULTHROP, Leslie (Associate, 1891), Receiver, Dwight Slate Mch. Co., and *for mail*, 620 Orange St., New Haven, Conn.

HULFELD, John E. (1908), V. P. and Genl. Mgr., Kansas City So. Ry., Thayer Bldg., Kansas City, Mo.

MULLER, Edward A. (1890), Secy. and Mgr., King Mch. Tool Co., Winton Pl., and *for mail*, 501 Mitchell Ave., Avondale, Cincinnati, O.

NELSON, Eric Hugo (1909), Ch. Draftsman, Geo F. Blake Mfg. Co., Cambridge and *for mail*, 15 Montague St., Arlington Hgts., Mass.

NEWCOMB, Robert Scott (Junior, 1909), Draftsman, Griscom-Spencer Co., Jersey City, and *for mail*, Palisade, N. J.

NORDMEYER, Louis C. (Junior, 1899), Secy. and Treas., Tait-Nordmeyer Engrg. Co., 1012 Liggett Bldg., and 4256 Shenandoah St., St. Louis, Mo.

PARKER, Levin S. (1908), Mech. Engr., Atlantic, Gulf & Pacific Co., 2407 Park Row Bldg., New York, and *for mail*, 1814 Ave. J., Flatbush, Brooklyn, N. Y.

PETTIS, Clifton D. (1905), Amer. Brake Shoe & Fdy. Co., 1414 McCormick Bldg., Chicago, Ill.

PITKIN, Arthur Frederick (Junior, 1907), Asst. Mech. Supt., Genl. Elec. Co., and 35 Waverly Pl., Schenectady, N. Y.

POMEROY, Harry D. (1892; 1904), 512 Dillaye Bldg., and 110 Baker Ave., Syracuse, N. Y.

PORTER, Hollis P. (1910), Ch. Engr. of Power, Cerro de Pasco Min. Co., La Fundicion, Peru, S. A.

PURINTON, Arthur James (1893), Genl. Supt., St. Joseph Ry., Light, Heat & Power Co., St. Joseph, Mo.

RATTLE, Paul S. (Junior, 1908), Charge of Pump and Compressor Dept., Mine & Smelter Supply Co., 17th and Blake Sts., Denver, Colo.

RAY, David H. (Associate, 1904), Ch. Engr., Bureau of Bldgs., Borough of Manhattan, 220 Fourth Ave., New York, N. Y.

RICHARDS, William A. (Junior, 1903), Charge of Mch. Shops, Forge and Fdy., Univ. H. S., Univ. of Chicago, Chicago, Ill.

SAR VANT, Wilbur Nason (Junior, 1907), Asst. Ch. Engr., Standard Turpentine Co. of Fla., 1016 Atlantic Natl. Bank Bldg., and *for mail*, 29 W. Monroe St., Jacksonville, Fla.

SELLEW, Ernest B. (Associate, 1907), Pres. and Mgr., Sellew Mch. Tool Co. Pawtucket, R. I.

SHERMAN, W. D. (1907), Huston Concrete Co., Zulueta 46, Havana, Cuba.

SLAUSON, Harold W. (Junior, 1908), Assoc. Editor, Recreation, 24 W. 39th St., New York, and *for mail*, cor. S. Broadway and Post St., Yonkers, N. Y.

SMITH, Allen C. (1902), Ch. Mech. Designer, Ottis Elev. Co., Yonkers, N. Y.

SMITH, Charles P. (Junior, 1888), Lower Pacific Mills, and *for mail*, 48 Olive Ave., Lawrence, Mass.

SMITH, Roy B. (Junior, 1905), Inspr., Pa. Lines West, and *for mail*, The Normandie, Columbus, O.

SMITH, William E. (Junior, 1908), Babcock & Wilcox Co., and *for mail*, 421 W. Lake Ave., Barberton, O.

STUTZ, C. C. (1900), Cons. Engr., Amer. Cement Tile Mfg. Co., Rm. 1309, 29 Broadway, New York, N. Y.

SUTER, Geo. A. (1883; 1893), 112 Wooster St., and *for mail*, 190 Riverside Drive, New York, N. Y.

SYMINGTON, E. Harrison (Associate, 1903), Mech. Expt., T. H. Symington Co., 616 Ry. Exch., Chicago, Ill.

TAIT, Roderick H. (1904), Pres., Tait-Nordmeyer Engrg. Co., 1012 Liggett Bldg., and 1368 Granville Pl., St. Louis, Mo.

TWINING, Wm. S. (1897), Ford, Bacon & Davis, 115 Broadway, New York, N. Y.

ULBRICHT, T. Carlile (Junior, 1908), Instr., Dept. of Power Engrg., Sibley College, Cornell Univ., and *for mail*, 426 E. Buffalo St., Ithaca, N. Y.

VAN VALKENBURGH, Ralph D. (1901; Associate, 1905), Engrg. Salesman, Taylor Iron & Steel Co., High Bridge, N. J., and *for mail*, 1602 Jefferson Ave., Scranton, Pa.

WALSH, Thomas J. (Junior, 1906), Stone & Webster Engrg. Corp., Boston, Mass., and *for mail*, 97 Howard Ave., Ansonia, Conn.

WEISSBLATT, Murray E. (Junior, 1907), Crocker-Wheeler Co., 1315 North Amer. Bldg., Philadelphia, Pa.

WHITE, James A. (Junior, 1900), Worcester Pressed Steel Co., and *for mail*. 167 Lincoln St., Worcester, Mass.

WILLIAMS, Alan Gillespie (Junior, 1909), Genl. Foreman, in charge Buffalo Shops, Pa. R. R., and *for mail*, 17 Johnson Park, Buffalo, N. Y.

WILLISTON, Arthur L. (1896; 1899), 27 Kilsyth Rd., Brookline, Mass.

WINSHIP, W. E. (1908), cor. 177th St. and Pinehurst Ave., New York, N. Y.

ZOWSKI-ZWIERZCHOWSKI, S. J. (1910), Asst. Prof. Mech. Engrg., Univ. of Mich., and *for mail*, 1304 Geddes Ave., Ann Arbor, Mich.

NEW MEMBERS

BARRON, Claude Mitchell (Junior, 1910), with R. W. Wiggin, Apartado 97-B, Mexico City, Mex.

CORLETTE, Glen H. (Junior, 1910), Fairbanks, Morse & Co., 566 Calle Moreno Buenos Aires, Argentine Republic, S. A.

LORING, Harrison, Jr. (1910), Treas. and Mech. Engr., R. S. Brine Transportation Co., 43 India St., Boston, Mass.

SAYER, Eugene Young (1910), V. P. and Genl. Mgr., Improved Equipment, Co., 60 Wall St., New York, N. Y.

SHAW, Joseph D. (1910), Cons. Engr., Partner, Fountain-Shaw Engrg. Co., 308 Andrews Bldg., Dallas, Tex.

VAN PATTEN, William Ensign (1910), Superintending Power and Light Plants, M. & E. Div., D. L. & W. R. R., Hoboken, and *for mail,* 48 Lunan Pl., Jersey City, N. J.

WIGGIN, Ralph Mitchell (1910), Apartado 97-B, Mexico City, Mex.

WYATT, Edgar William (1910), Cons. Engr., 632 Marlborough Rd., Brooklyn, N. Y.

DEATHS

JOHNSON, Lewis, May 26, 1910.
HALL, Frederick Bellows, October 27, 1910.
ROBINSON, Stillman W., October 31, 1910.
SHANTZ, Oliver S., September 1910.

GAS POWER SECTION

CHANGES OF ADDRESS

COLWELL, James V. V. (1908), Mem.Am.Soc.M.E.
GORE,, Warren W. (1909), Mem.Am.Soc.M.E.
HOWARD, Charles A. (1908), Mem.Am.Soc.M.E.
McMULLIN, Frank V. (1908), Mem.Am.Soc.M.E.
ULBRICHT, T. C. (1908), Mem.Am.Soc.M.E.
WINSHIP, W. E. (1909), Mem.Am.Soc.M.E.

STUDENT MEMBERSHIP

BERGERT, H. A. (Student, 1910), care C. R. I. & P. R. R. Shop, Silvis, Ill.
BOHNSTENGEL, Walter (Student, 1909), 1111 Kentucky St., Lawrence, Kan.
BUTLER, N. R. (Student, 1909), 1600 Madison Ave., Baltimore, Md.
CARR, W. deL. (Student, 1909), 32 Vine St., West Lynn, Mass.
CUMPSTON, E. H., Jr. (Student, 1909), 2727 P St., Washington, D. C.
ESTES, G. H. (Student, 1910), 112 Newbery St., Boston, Mass.
GRIFFITH, F. H. (Student, 1909), 41 W. 33d St., Chicago, Ill.
GRAY, C. F. (Student, 1910), 333 W. Washington St., Madison, Wis.
KELLEY, P. W. (Student, 1910), 1254 Michigan Ave., Chicago, Ill.
KONSTANKEWICZ, M. J. (Student, 1910), 303 N. Shamokin St., Shamokin, Pa.
KRAATZ, K. L. (Student, 1910), 224 N. Brooks St., Madison, Wis.
McCAIN, W. R. (Student, 1910), present address unknown.
MATTERN, J. Fred. (Student, 1910), University Club, Altoona, Pa.
MORGAN, Henry (Student, 1910), 2533 N. Grand Ave., St. Louis, Mo.
MUFFLY, Walter W. (Student, 1910), Hotel Morgan, South Sharon, Pa.
NELSON, J. E. (Student, 1909), East Ryegate, Vt.
OAKLEY, Walter W. (Student, 1910), 502 N. Market St., Kokomo, Ind.
PARMELY, J. C. (Student, 1909), 128 Smith St., Kewanee, Ill.
PAUL, Harry J. (Student, 1910), 930 Roscoe St., Chicago, Ill.
PIMPER, T. F. (Student, 1910), 1302 30th St., Washinton, D. C.
PURDY, Donald F. (Student, 1910), 157 N. 20th St., Philadelphia, Pa.
RICHEY, A. L. (Student, 1909), 915 E. State St., Ithaca, N. Y.
RUSSELL, Foster (Student, 1910), 39 Cumberland St., Boston, Mass.
SCHUSTER, George (Student, 1909), 905 Fourth Ave., Rock Island, Ill.
STEINBECK, C. E. (Student, 1909), Burlingame, Cal.
WEAVER, H. E. (Student, 1910), 208 S. 10th St., Columbia, Mo.
YODER, Jacob H. (Student, 1910), Sch. for Apprentices, 1120 13th Ave., Altoona, Pa.

NEW MEMBERS

BROOKLYN POLYTECHNIC INSTITUTE

WICHUM, Victor (Student, 1910), 241 Covert St., Brooklyn, N. Y.

COLUMBIA UNIVERSITY

CLARK, S. M. (Student, 1910), 427 Franklin Ave., Brooklyn, N. Y.
FREDERICHS, W. (Student, 1910), 53 Lewis St., Tompkinsville, S. I., N. Y.
HENDRICKSON, M. E. (Student, 1810), 536 Dean St., Brooklyn, N. Y.

MURPHY, E. A. (Student, 1910), Livingston Hall, Columbia Univ., New York, N. Y.
RILEY, W. L. (Student, 1910), 614 W. 113th St., New York, N. Y.
SELLEW, W. H. (Student, 1910), 78 E. 79th St., New York, N. Y.

CORNELL UNIVERSITY

BELLINGER, E. W. (Student, 1910), 201 Oak Ave., Ithaca, N. Y.
BOGARDUS, A. G. (Student, 1910), 6 South Ave., Ithaca, N. Y.
HOLDEN, R. O. (Student, 1910), 133 Linden Ave., Ithaca , N. Y.
OVEROCKER, R. H. (Student, 1910), 109 College Ave., Ithaca, N. Y.
TRUMP, C. C. (Student, 1910), 103 Highland Pl., Ithaca, N. Y.

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

BESSE, E. E. (Student, 1910), 39 Cumberland St., Boston, Mass.
BROWNLEE, Robt. B. (Student, 1910), 38 St. Botolph St., Boston, Mass.
BURLEIGH, W. S. (Student, 1910), 107 W. Central St., Natick, Mass.
FERRY, Ralph M. (Student, 1910), 134 W. Newton St., Boston, Mass.
MEISEL. O. C. F. (Student, 1910), 10 Upland Ave., Dorchester, Mass.

UNIVERSITY OF ILLINOIS

ALLEN, G. B. (Student, 1910), 706 S. 2d St., Champaign, Ill.
CONNARD, A. F. (Student, 1910), 908 S. 5th St., Champaign, Ill.
DUTT, M. L. (Student, 1910), 1012 W. Oregon St., Urbana, Ill.
FAISON, Wm. A. (Student, 1910), 212 E. Green St., Champaign, Ill.
HAGEDORN, F. A. (Student, 1910), 706 S. 2d St., Champaign, Ill.
HASSELQUIST, E. J. (Student, 1910), 934 W. Illinois St., Urbana, Ill.
HERRCKE, E. A. (Student, 1910), 706 S. 2d St., Champaign, Ill.
KNAUSS, (Student, 1910), 805 W. Illinois St., Urbana, Ill.
PHILLEO, G. W. (Student, 1910), 1107 Springfield Ave., Urbana, Ill.
STUEBING, A. F. (Student, 1910), 311 E. Healy St., Champaign, Ill.
WHITNALL, C. A. (Student, 1910), 1002 S. 6th St., Champaign, Ill.

YALE UNIVERSITY

BAKER, F. H. (Student, 1910), 133 Wall St., New Haven, Conn.
BORKETT, D. B. (Student, 1910), Byers Hall, New Haven, Conn.
BRADY, G. S. (Student, 1910), 872 Yale P. O., New Haven, Conn.
COOK, H. J. (Student, 1910), 70 Trumbull St., New Haven, Conn.
DEMAREST, L. McG. (Student, 1910), 166 Sheff. Vanderbilt, New Haven, Conn.
DRAVO, H. D. (Student, 1910), 164 Sheff. Vanderbilt, New Haven, Conn.
DuBOSQUE, C. (Student, 1910), 166 Sheff. Vanderbilt, New Haven, Conn.
GRAFF, W. (Student, 1910), 246 Dwight St., New Haven, Conn.
HAYES, H. E. (Student, 1910), 148 Grove St., New Haven, Conn.
JOHNSON, D. A. (Student, 1910), 177 Sheff. Vanderbilt, New Haven, Conn.

JONES, M. F. (Student), 1910, 96 Wall St., New Haven, Conn.
KELLY, R. A. (Student, 1910), Temple St., New Haven, Conn.
KNABLE, G. E. (Student, 1910), 124 Prospect St., New Haven, Conn.
MANNY, W. R. (Student, 1910), 166 Sheff. Vanderbilt, New Haven, Conn.
MEEKER, L. A. (Student, 1910), 167 Sheff. Vanderbilt, New Haven, Conn.
MILLS, C. G. (Student, 1910), 124 Prospect St., New Haven, Conn.
PERLEY, A. D. (Student, 1910), Byers Hall, New Haven, Conn.
PRUDDEN, J. M. (Student, 1910), Byers Hall, New Haven, Conn.
REEVE, A. B. (Student, 1910), Byers Hall, New Haven, Conn.
RUGE, J. H. (Student, 1910), 746 Yale Sta., New Haven, Conn.
WATZEK, J. W. (Student, 1910), Byers Hall, New Haven, Conn.

COMING MEETINGS

DECEMBER—JANUARY

Advance notices of annual and semi-annual meetings of engineering societies are regularly published under this heading and secretaries or members of societies whose meetings are of interest to engineers are invited to send such notices for publication. They should be in the editor's hands by the 15th of the month preceding the meeting. When the titles of papers read at monthly meetings are furnished they will also be published.

THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

December 27–January 3, Minneapolis and St. Paul, Minn. Secy., L. O. Howard, Smithsonian Institution, Washington, D. C.

AMERICAN CHEMICAL SOCIETY

December 27–30, meeting with the American Association for the Advancement of Science, Minneapolis, Minn. Secy., Charles L. Parsons, Durham, N. H.

THE AMERICAN INSTITUTE OF ARCHITECTS

January 17–19, annual convention, San Francisco, Cal. Papers: The Development of Architecture on the Pacific Coast and the Rehabilitation of the City of San Francisco, The Aesthetic Problems of and what the Coast has Accomplished in City Planning, The Salient Points of the Architecture of the Northern Pacific Coast, by Chas. H. Bebb; History and Present Status of the California Missions, by A. B. Benton. Secy., Glenn Brown, The Octagon, Washington, D. C.

AMERICAN INSTITUTE OF CHEMICAL ENGINEERS

December 7–10, annual meeting, New York. Papers: Chemical Engineering Education, F. W. Frerichs, F. W. Atkinson, M. C. Whitaker; The Fitzgibbons Boiler, Jerome Alexander; Manufacture of Hydrated Lime, Richard K. Meade; The Evolution of Portland Cement Processes, Chas. F. McKenna; Manufacture of Lignite Briquettes, Henry S. Renaud; Bleaching Oils with Fullers Earth, David Wesson; Action of Fruit Juices on Metallic Containers, E. Gudeman; Vacuum Distilling Apparatus, P. B. Sadtler; Symposium on Sewerage Disposal, Geo. C. Whipple, R. Hering, Mem.Am.Soc.M.E., Geo. A. Soper, N. S. Hill, Jr., Chas. E. A. Winslow. Secy., J. C. Olsen, Polytechnic Institute, Brooklyn, N. Y.

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

January 13, 29 W. 39th St., New York. Secy., R. W. Pope.

AMERICAN MATHEMATICAL SOCIETY

December 28–29, Columbia University, New York; December 29–30, University of Chicago ,Chicago, Ill. Secy., F. N. Cole, 501 W. 116th St. New York.

AMERICAN SOCIETY OF CIVIL ENGINEERS

January 18–19, annual meeting, 220 W. 57th St., New York. Secy., C. W. Hunt.

AMERICAN SOCIETY OF HEATING AND VENTILATING ENGINEERS

January 24–26, annual meeting, 29 W. 39th St., New York. Secy., W. M Mackay, Box 1818.

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

December 6–9, annual meeting, 29 W. 39th St., New York. December 23, joint meeting with the American Institute of Electrical Engineers, Boston, Mass. Secy., Calvin W. Rice.

AMERICAN SOCIETY OF REFRIGERATING ENGINEERS

December 5–6, annual meeting, New York. Secy., W. H. Ross, 154 Nassau St.

ASSOCIATION OF AMERICAN PORTLAND CEMENT MANUFACTURERS

December 12–14, annual convention, New York. Secy.,Percy H.Wilson, Land Title Building, Philadelphia, Pa.

AUTOMOBILE EXPOSITION

December 31–January 7, Grand Central Palace, New York. Secy., B. Briscoe, 7 E. 42d St.

BROOKLYN ENGINEERS CLUB

December 1, 117 Remsen St., Brooklyn, N. Y. Paper: The Gyroscope, Elmer A. Sperry. Secy., Joseph Strachan.

CIVIL ENGINEERS SOCIETY OF ST. PAUL

January 9, annual meeting, Old State Capitol Bldg., St. Paul, Minn. Secy., D. F. Jurgensen, 116 Winter St.

ELECTRICAL CONTRACTORS ASSOCIATION OF NEW YORK STATE

January 10, ex-semi annual meeting, Albany, N. Y. Secy., Geo. W. Russell, Jr., 25 W. 42d St., New York.

ENGINEERS' CLUB OF ST. LOUIS

December 7, annual meeting, 3817 Olive St., St. Louis, Mo. Secy., W. W. Homer, 5203 Maple Ave.

ENGINEERS SOCIETY OF PENNSYLVANIA

January 16, annual meeting ,Harrisburg, Pa. Secy., Edw. R. Dasher, Gilbert Bldg.

ENGINEERS SOCIETY OF WESTERN PENNSYLVANIA

January 17, annual meeting, Oliver Bldg., Pittsburg, Pa. Secy., E. K. Hiles, 803 Fulton Bldg.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS

January 25–27, annual meeting, East St. Louis, Ill. Secy., E. E. R. Tratman, 1636 Monadnock Blk., Chicago, Ill.

INDIANA ENGINEERING SOCIETY

January 12–14, annual meeting, Indianapolis, Ind. Secy., Chas. Brossman.

NATIONAL ASSOCIATION OF CEMENT USERS

December 12–20, annual convention, Concert Hall, Madison Square Garden, New York. President Richard L. Humphrey, Harrison Bldg., Philadelphia, Pa.

THE NATIONAL CIVIC FEDERATION

January 12–14, annual meeting, Hotel Astor, New York. Chairman Executive Council, Ralph M. Easley, 1 Madison Ave.

NATIONAL COMMERCIAL GAS ASSOCIATION

December 5–13, annual convention, Boston, Mass. Pres., L. S. Bigelow, 1374 Main St., Buffalo, N. Y.

NATIONAL GAS AND GASOLINE ENGINE TRADES ASSOCIATION

December 12–15, annual meeting, Racine, Wis. Secy., A. Stritmatter, Cincinnati, O.

NEW ENGLAND RAILROAD CLUB

December 13, New American House, Boston, Mass. Paper: The evolution of Air Brakes Made Necessary to meet modern Train Conditions, H. N. Lamb. Secy., Geo. H. Frazier, 10 Oliver St.

NEW JERSEY SANITARY ASSOCIATION

December 2–3, annual meeting, Lakewood, N. J. Papers; Two Years' Experience in Dust Suppression on Roads, James Owen; Latest Phases of Sewage Purification, Rudolph Hering, Mem.Am.Soc.M.E.; The Possible Deleterious Effects of Illuminating Gas upon the Human Economy and the Probable Extent to which they obtain, C. E. Forstall. Secy., J. A. Exton, 75 Beech St., Arlington.

SHORT LINE RAILROAD ASSOCIATION

December 15, annual meeting. Secy., John N. Drake, 60 Wall St., New York.

SOCIETY OF AUTOMOBILE ENGINEERS

January 11–12, annual meeting, New York. Pres., Howard E. Coffin, 1451 Broadway.

MEETINGS IN THE ENGINEERING SOCIETIES BUILDING

Date	Society	Secretary	Time
1	Blue Room Engineering Society	W. D. Sprague	8.15 p.m.
6, 7, 8, 9	American Society Mechanical Engineers	C. W. Rice	All day
7	Wireless Institute	S. L. Williams	8.00 p.m.
8	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
9	American Institute Electrical Engineers	R. W. Pope	8.00 p.m.
16	New York Railroad Club	H. D. Vought	8.15 p.m.
20	New York Telephone Society	T. H. Lawrence	8.15 p.m.
28	Municipal Engineers of New York	C. D. Pollock	8.15 p.m.
January			
4	Wireless Institute	S. Williams	7.30 p.m.
5	Blue Room Engineering Society	W. D. Sprague	8.15 p.m.
10	American Society Mechanical Engineers	C. W. Rice	8.15 p.m.
12	Illuminating Engineering Society	P. S. Millar	8.15 p.m.
13	American Institute Electrical Engineers	R. W. Pope	8.15 p.m.
17	New York Telephone Society	T. H. Lawrence	8.15 p.m.
20	New York Railroad Club	H. D. Vought	8.15 p.m.
24, 25, 26	American Society of Heating and Ventilating Engineers	W. M. Mackay	All day
25	Municipal Engineers of New York	C. D. Pollock	8.15 p.m.

CURRENT BOOKS

THE HISTORY OF THE TELEPHONE. By Herbert N. Casson. *Chicago, A. C. McClurg Co., 1910.* Cloth, 8vo, 316 pp., fully illustrated. Price, $1.50.

Contents: The Birth of the Telephone; The Building of the Business; The Holding of the Business; The Development of the Art; The Expansion of the Business; Notable Users of the Telephone; The Telephone and National Efficiency; The Telephone in Foreign Countries; The Future of the Telephone; Index.

COMPOSITION AND HEAT TREATMENT OF STEEL. By E. F. Lake. *New York, McGraw-Hill Book Co., 1910.* Cloth, 12 vo, illustrated. Price $2.50.

Contents: The Making of Pig Iron; Bessemer Process of Converting Iron into Steel; Open-Hearth Process for Making Steel: Crucible Process of Steel Making; Electric Furnaces for Steel Making; Ingredients of and Materials used in Steel; Working Steel into Shape; Furnaces and Fuels used for Heat-Treatment; Annealing Steel; Hardening Steel; Tempering Steel; Carbonizing.

A TEXT-BOOK OF ELEMENTARY FOUNDRY PRACTICE. For the Use of Students in Colleges and Secondary Schools. By William Allyn Richards. *New York, The Macmillan Company, 1910.* Cloth, 8vo. 121 pp. Price, $1.25 net.

Contents: Introduction; Definition; Materials; Tools; Principles of Molding; Molding Exercises without Core; Matches; Molding Exercises with Green-Sand Cores; Dry Cores; Molding Exercises with Dry Cores; Miscellaneous Exercises; Open Molding, Sweep and Strike Work; Dry-Sand Molding; Cupola Practice or Melting; Cleaning Castings; Chilled and Malleable Castings; Brass Molding; Glossary; Appendix; Index.

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Univ. of Wisconsin, Madison, Wis.	November 9	C. C. Thomas	A. MacArthur	A. Wegner
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	1910			
Univ. of Maine, Orono, Me.	February 8	Arthur C. Jewett	H. N. Danforth	A. H. Blaisdell
Univ. of Arkansas, Fayetteville, Ark.	April 12	B. N. Wilson	C. B. Boles	W. Q. Williams
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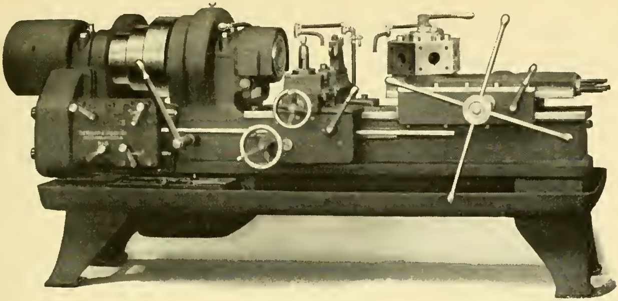

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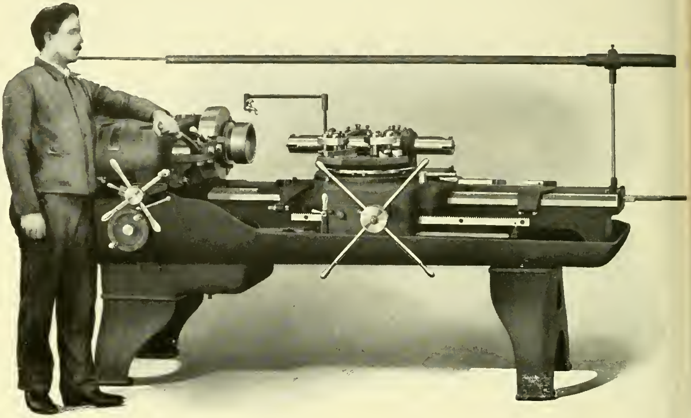

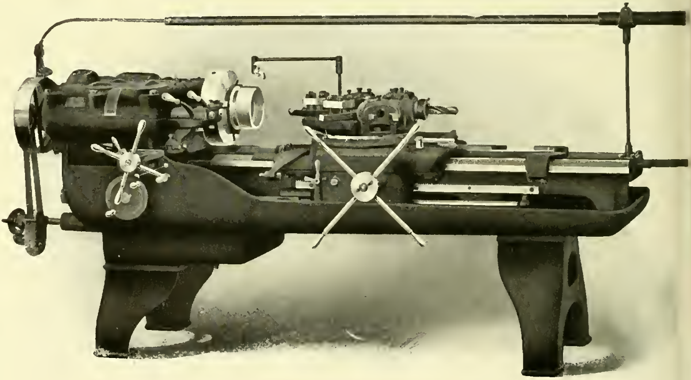

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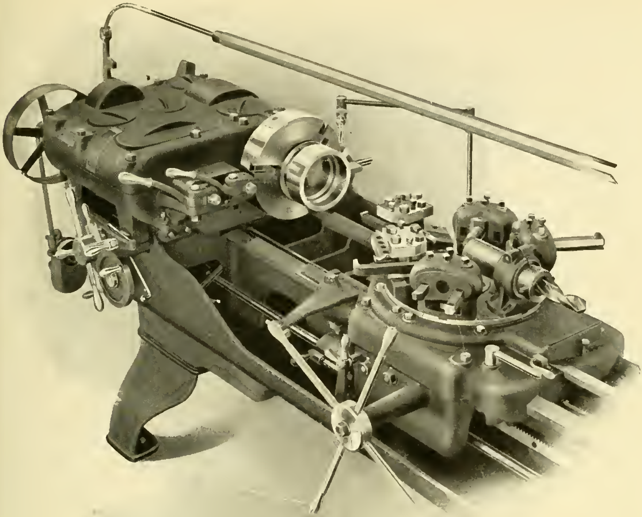

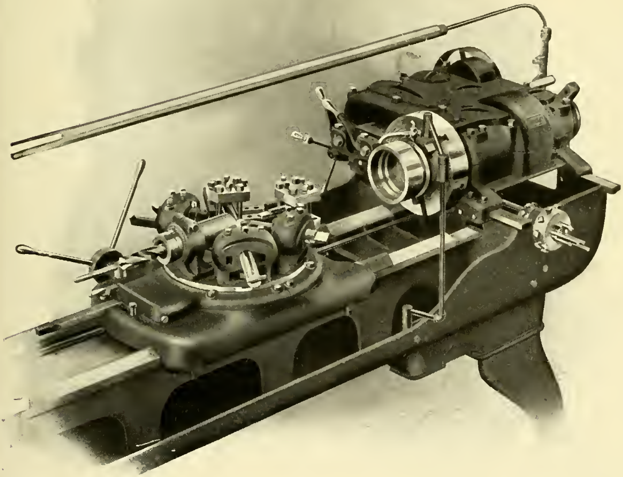

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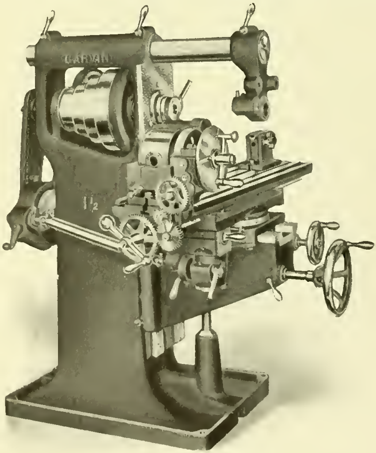

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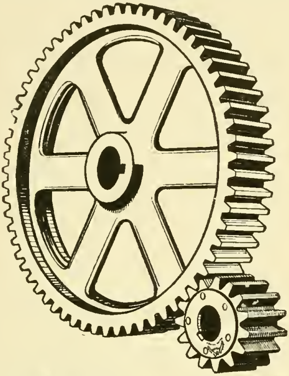

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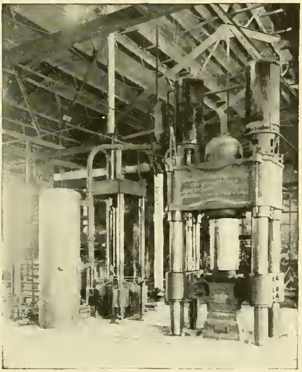

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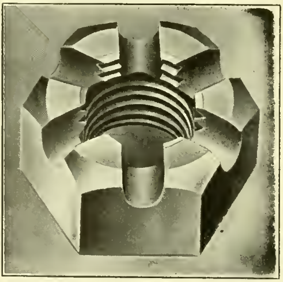

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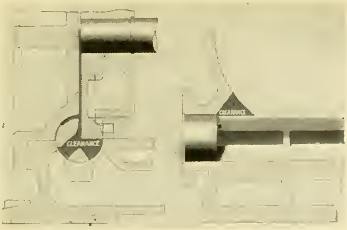

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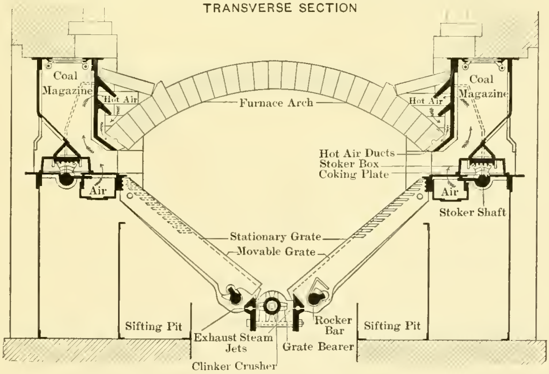

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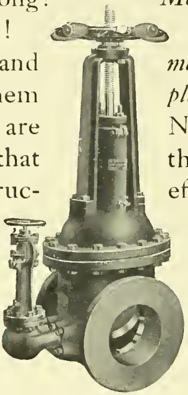

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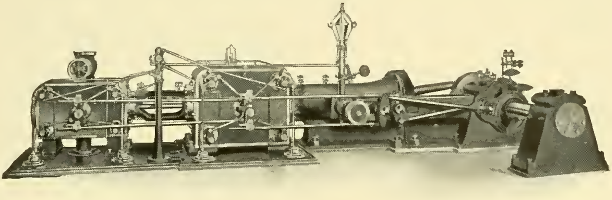
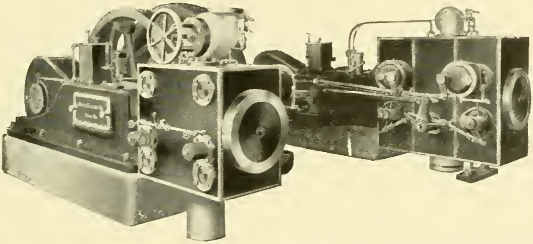


HEWES & PHILLIPS IRON WORKS NEWARK N. J.



BALL CORLISS ENGINE

With Non-Detaching Valve Gear

It was the drop cut-off gear which made the Corliss Engine successful and economical for slow speeds

The feature which distinguishes our High and Medium Speed Engines and makes them superior to all other four-valve engines is our *patented non-detaching valve gear.*

This gear by positive action gives the valves the *same movement* that the *drop cut-off* of the slow speed Corliss *produces* by picking up and dropping them.

The valve gear opens and closes the valves at the *proper* time, and holds the valves *absolutely still* during over *half a revolution.*

The valves are given the movement necessary for the *greatest durability* and *tightness,* and the *best form* of valve is made possible.

This engine marks the extreme limit of excellence so far reached in economy and quiet running.

BALL ENGINE CO., Erie, Penna.

IMMUNE TO the evils of EXPANSION

ROTHCHILD ROTARY GATE VALVE

HAS

PROVED

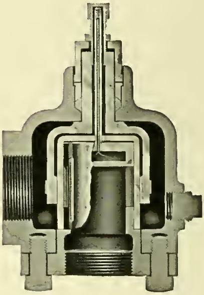
ITS

SUPERIOR COMPARATIVE MERITS

FOR

BOILER BLOW-OFF, ETC.

BECAUSE IT



meets requirements perfectly without repairs or complaint

SPECIFIED AND USED BY LEADING ENGINEERS
MODERN POWER PLANTS

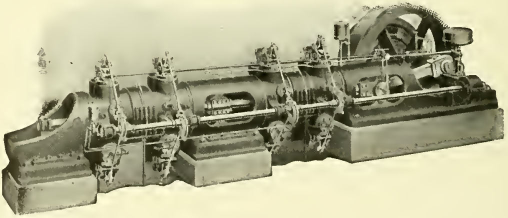
JOHN SIMMONS CO., 110 Centre St., New York, N. Y.

BUCKEYE GAS ENGINES

FOUR CYCLE - DOUBLE ACTING

For Natural and Producer Gas

75 to 10,000 B. H. P.



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BUCKEYE ENGINE COMPANY

SALEM, OHIO

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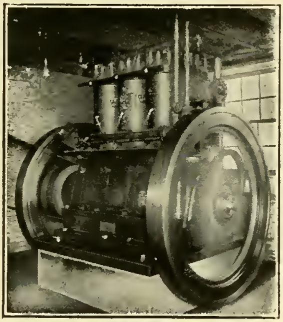

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Reliable, Economical, Simple and Safe.

25 years leadership of Vertical Gas Engine Design.

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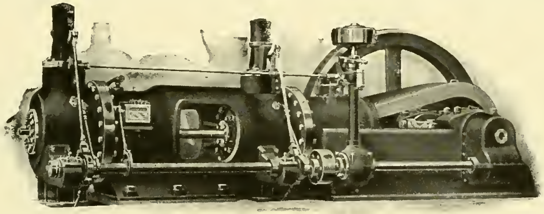

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POINTS OF MERIT

Heavy overload capacity. Close regulation. Positive lubrication. Positive circulation of cooling water. No joints between combustion chamber and water jackets. All valve cages removable.

The most reliable and economical motive power obtainable
Ask your consulting engineer to investigate

STRUTHERS-WELLS CO., Warren, Pa.

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Successors to
EDWARD KENDALL & SONS
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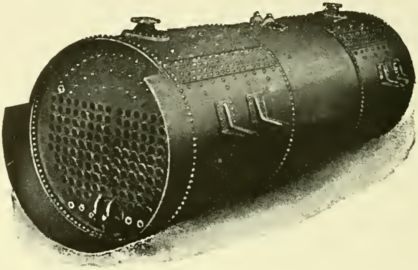

Manufacturers of

Return Tubular, Water Tube, internally fired and other types of Boilers; Smoke Stacks, Tanks, Etc.

Works:—SOUTH FRAMINGHAM, MASS.

Sales Office: 131 State St., Boston

CUT YOUR COAL BILL IN TWO!
Ask Murray Iron Works Company Burlington, Iowa, About it.
TO — COAL WOOD & CO. Dr.
TERMS CASH
PLEASE REMIT
2000 tons Coal $4400.00
EFFICIENCY
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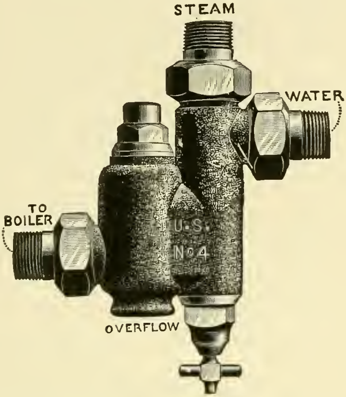
SUCCESS HINGES RIGHT HERE
ON A MURRAY POWER PLANT COMPLETE

U. S. Automatic Injectors have an International Reputation for Superiority



They have just as firm a foothold abroad as at home. Only genuine merit has placed the "U. S. Automatic" in this position. The more particular you are about securing reliable boiler feeding—the better it pleases us—for the **U. S. is a reliable boiler feeder.**

Send for our Engineers' "Red Book"—it slips right into the vest pocket, small in size, but large in information.

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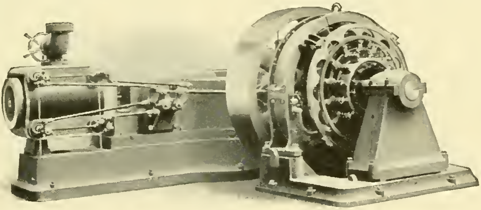
DETROIT, MICH.



RIDGWAY FOUR-VALVE ENGINES

have established a record for *maximum economy* among reciprocating steam engines.

¶ If you are interested in the saving of oil, water and fuel, you should carefully investigate the unusual claims we make for these machines.

Bulletin No. 22 H describes and illustrates the principal features of gearing and important details

RIDGWAY DYNAMO AND ENGINE CO.
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THE BABCOCK & WILCOX COMPANY
85 LIBERTY STREET, NEW YORK

Water Tube Steam Boilers
STEAM SUPERHEATERS MECHANICAL STOKERS

Works: BARBERTON, OHIO BAYONNE, N. J.

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are made from Standard and Extra Heavy pattern, both brass and iron body, in several different styles—horizontal, angle, vertical, swing. All are fitted with the Jenkins Disc, thus assuring a tight seat. And as the Jenkins Disc takes practically all the wear, the seat is seldom injured, and valves give long and satisfactory service without requiring attention or repair.

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For lubricating graphite you can't get better than

DIXON'S FLAKE GRAPHITE

Pure, free from grit, reliable and well-known. You're sure when you sell Dixon's. We'll tell you more on request.

JOSEPH DIXON CRUCIBLE CO.
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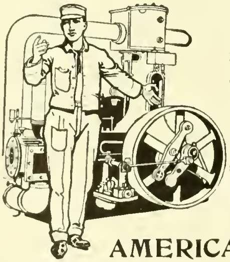

POWER FOR 2c A KW. HOUR

If you are paying more than this for lighting and power current you are throwing good money away,—might just as well get a K.W. hr. for two cents and put the difference in your pocket. Hundreds of plants are already running as economically as this by using

AMERICAN BALL ANGLE COMPOUND
DIRECT CONNECTED UNITS

The Angle Compound Unit is built especially for isolated plant service. It has superior steam economy, gets twice as much power on the same floor space as a simple engine, needs very little attention (as it has no complicated valve gears and automatic lubrication), sets up absolutely no vibrations, and is therefore suitable for use in apartment houses, hospitals, hotels, etc. Write for catalog.

AMERICAN ENGINE COMPANY
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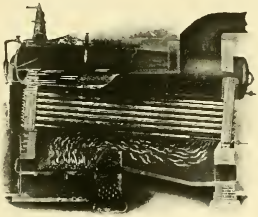

FRANKLIN WATER-TUBE **BOILER**

BUILT BY

Franklin Boiler Works Co.

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HEINE WATER TUBE **BOILERS**

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In units of from 50 to 600 H. P.

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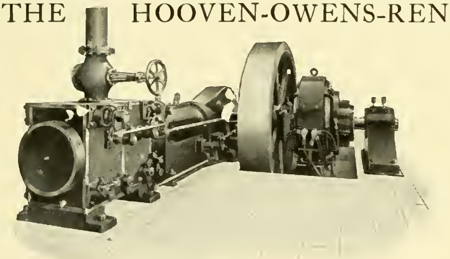

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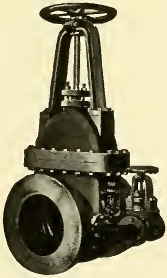
HAMILTON CORLISS ENGINES

Standard of Merit

Works at

HAMILTON, OHIO



WE SPECIALIZE

We concentrate our entire attention on valves and hydrants and do not have a line of miscellaneous sundries such as fittings, boiler trimmings, etc., to divide our interests. Thus we can give valves particular attention.

The result of this concentrated effort is shown in Kennedy Valves—it shows in their design, workmanship and finish.

THE KENNEDY VALVE MFG. CO.

ELMIRA, N. Y.

Superheated Steam

Papers read before

The American Society of Mechanical Engineers

from 1890 to 1908

The Society has a limited number of copies of papers on Superheated Steam which have been presented before it. Orders will be filled until the supply is exhausted.

No.		Price to Members	Non-Members
359	Tables of the Properties of Steam, V. Dwelshauvers-Dery	$.15	$.30
689	Superheated Steam, Facts, Data and Principles, R. H. Thurston	25	50
853	Pumping Engine Test with Superheated Steam, E. H. Foster	5	10
905	The Practical Application of Superheated Steam, Geo. A. Hutchinson	15	30
906	Superheated Steam, Ernest H. Foster	5	10
1024	Tests of a Compound Engine using Superheated Steam, D. S. Jacobus	10	20
1150	The Flow of Superheated Steam in Pipes, E.H. Foster	5	10
1151	Superheat and Furnace Relations, R. P. Bolton	5	10
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1196	Thermal Properties of Superheated Steam, R. C. H. Heck	15	30
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ADVERTISING SUPPLEMENT

SECTION 3

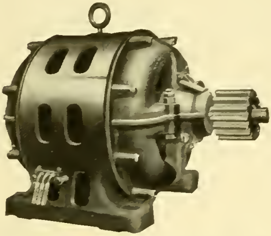
Electrical Equipment

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
Directory of Mechanical Equipment - - - Section 6

Westinghouse Type "MS" Mill Motors

Squirrel-Cage
Alternating-Current

A partial list of iron and steel manufacturers who, by repeated orders have recognized the unequalled electrical and mechanical features of Type "MS" Mill Motors follows:



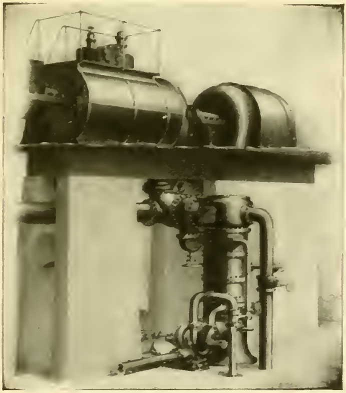
American Iron & Steel Co.
America Steel & Wire Co.
Cambria Steel Co.
Carnegie Steel Co.
Indiana Steel Co.
Jones & Laughlin Steel Co.
Oliver Iron & Steel Co.
Pennsylvania Steel Co.
Spang Chalfant Co.
Spanish-American Iron Co.
Tennessee Coal, Iron & R. R. Co.
Wheeling Steel & Iron Co.

SEE CIRCULAR No. 1164

Westinghouse Electric & Manufacturing Co., Pittsburg Pa.

Sales Offices in all Large Cities

There is no mistaking the opinion of this man as to Westinghouse Leblanc Condensers; read what he says:



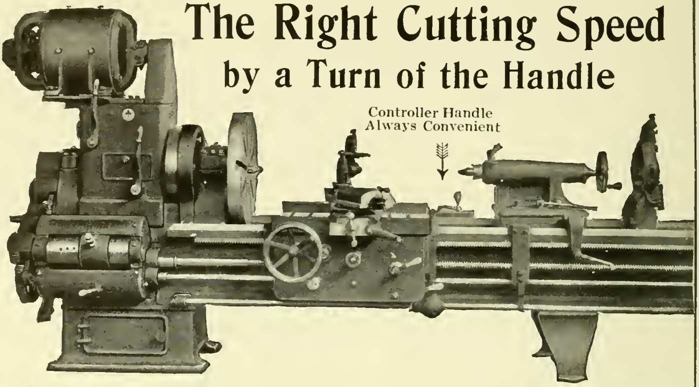
"We have had in operation continuously for 14 months, one 500 h. p. condenser, 24 hours per day. I wish to say that during that time the condenser has cost us $4.50 for lubrication, and not one penny has been spent for repair in any way, shape, form or fashion. There is nothing to get out of order, not a single valve to renew (which is very expensive in the old type of condenser). I have had quite a deal of experience with condensers and I can honestly say the Leblanc Condenser is, by far, the most efficient and economical condenser on the market to-day.

I base my decision on the high vacuum the condenser will carry throughout the year. We carry 29 inches all the time, not by gauge, but by mercury column, which must be correct."

SEND FOR CIRCULAR 501

THE WESTINGHOUSE MACHINE COMPANY
PITTSBURG, PA.

The Right Cutting Speed
by a Turn of the Handle



General Electric Motor Drive

When installing a mechanical drive, the designing engineer sometimes knows the kind of work to be done and can select pulley diameters to approximate the best cutting speeds.

This is not so with machine repair shops, where the work and metal are constantly changing. Here it is practically impossible to foretell the economical cutting speeds. Necessarily a compromise is made, and a mechanical drive installed with speed steps that are often unsuited to the work being done.

For all work requiring variable speed the General Electric Motor Drive gives the best cutting speed for any cut on any kind of metal by the mere turn of a handle placed where most convenient.

The mechanic sets up his work, sets his tool and then quickly raises the speed until the tool has all it can stand. This saves time—at least an hour or two a day.

No time lost hunting for shifter sticks and no unsuccessful attempts at jumping the belt up or down only to find the speed selected has burnt and taken the edge off the tool. No costly rolling stock tied up through loss of time when scheduled for a run. Just *the right speed instantly by a turn of the handle.*

The General Electric Company, through its competent corps of engineers, is enabled to recommend the latest, most economical applications of electric power in railroad shops. Write them for advice concerning any power problem that may be encountered.

General Electric Company

Largest Electrical Manufacturer in the World

Principal Office:
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Sales Offices in all Large Cities
2567

GAS - ELECTRIC UNITS built by Allis-Chalmers Company offer the most satisfactory answer to the modern demand for the development of power with low costs for fuel and maintenance.

ALLIS-CHALMERS COMPANY

Offices in all principal cities

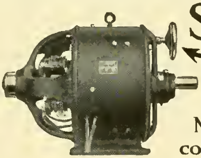
YEAR BOOKS

The Society wishes to have a file of year books or catalogues complete since its formation. Will members who have any of the following numbers either send them to the Society or correspond with the Secretary

No. 2, 1881	No. 6, 1885	No. 13, 1892, July
No 3, 1882	No. 7, 1886	No. 14, 1893, January
No. 5, 1884	No. 12, 1891, July	No. 14, 1893, July

The American Society of Mechanical Engineers
29 West 39th Street, New York

RELIANCE ADJUSTABLE SPEED MOTOR



This wheel controls the speed changes
No electrical controller needed

THIS is the only motor which by simple means gives the power, overload capacity and really accurate speed adjustment over wide ranges necessary to meet the changing conditions which are constantly arising in machine tool work. It gives a constant horsepower output at all speeds, stands heavy overloads, holds a set speed steadily under changing loads and shows a high efficiency. In contrast to the limited number of speeds and small ranges obtained with an electrical controller our method gives an unlimited number of running speeds throughout wide ranges.

The starting and stopping of the motor is entirely separate from the speed control so that it is possible to use a rugged automatic starter which makes the entire equipment "fool-proof."

We are prepared to furnish all types of motors for the complete equipment of machine shops We will also design and manufacture all brackets, gears, etc., for converting your belt driven tools to motor drive. Ask us to send a copy of our Folder No. 10-S which contains interesting information for the machine tool user.

RELIANCE ELECTRIC & ENGINEERING CO.

710 Caxton Building, Cleveland, Ohio

Shop Management

Papers read before

The American Society of Mechanical Engineers from 1890 to 1909

The Society has a limited number of copies of papers on Shop Management which have been presented before it. Orders will be filled until the supply is exhausted.

Vol. No.		Price List
23—928	Bonus System of Rewarding Labor, H. L. Gantt . . .	.20
24—998	Drawing Office Equipment, John McGeorge	.20
5—143	Drawing Office System, H. R. Towne	.10
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25–1012	Is Anything the Matter with Piece Work? F. Richards	.20
24–1001	Machine Shop Problem, C. Day	.20
18—711	Method of Determining Selling Price, H. M. Lane . .	.20
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25–1011	Modifying System of Management, H. L. Gantt . . .	.10
16—647	Piece Rate System, F. W. Taylor	.30
12—449	Premium Plan of Paying for Labor, F. A. Halsey	.20
8—256	Problem in Profit Sharing, Wm. Kent	.30
24–1003	Shop Management, F. W. Taylor	.90
25–1010	Slide Rules for the Machine Shop, C. G. Barth	.20
30–1221	Training Workmen, H. L. Gantt	.10
		$3.70

$3.50 for the set.

Members' rates are half the list price.

Address Calvin W. Rice, Secretary, 29 West 39th St., New York

ADVERTISING SUPPLEMENT

SECTION 4

Hoisting and Conveying Machinery Power Transmission

Machine Shop Equipment - - - - - Section 1
Power Plant Equipment - - - - - Section 2
Electrical Equipment - - - - - Section 3
Hoisting and Conveying Machinery. Power Transmission - Section 4
Engineering Miscellany - - - - - Section 5
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Dirt, Dust and Accident Proof

A Triplex Block with dirt-proof cover.

THE gear system in a Triplex Block isn't afraid of hard service. Like all good machines, its only enemy is dirt. But the pressed steel gear cover that we put on it not only protects it from dirt and dust, but when a careless workman lets it drop, it just gets dented a little—it won't break.

That's one of the reasons why it lasts a lifetime. *You* may have one by just asking us or *your* nearest dealer.

Chain Blocks
- **4 Styles:** Differential, Duplex, Triplex, Electric.
- **42 Sizes:** An eighth of a ton to forty tons.
- **300 active stocks** ready for instant call all over the United States.

The book of Hoists tells much—for a post card

The Yale & Towne Mfg. Co.

Makers of Yale Products
Locks, Padlocks, Builders' Hardware,
Door Checks and Chain Hoists

9 Murray Street,
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Local Offices: Chicago Boston Washington San Francisco

OTIS ELEVATORS

ALL TYPES

FOR EVERY KIND OF SERVICE

Otis Elevator Company

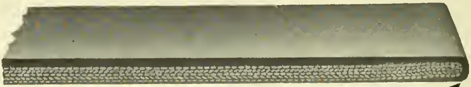
OFFICES

IN ALL PRINCIPAL CITIES OF THE WORLD

Conveyor Belt User

Have you had trouble with the Edge of Your Belt?
Does it come loose, peel, break off, or wear away?
Then let your next belt be a

Goodrich Conveyor Belt



Edge Construction—Goodrich Conveyor Belt →

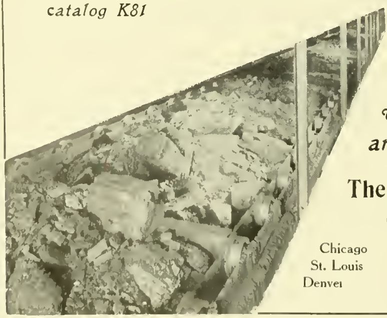
This is the best edge ever put on a conveyor belt. Notice how the top cover is carried around into the back cover without leaving a thin corner to break loose. No square corners to catch. No molded edge to peel off. The edge is formed by a special process of our own and is vulcanized before the rest of the belt so that the adhesion of the corner around the edge is as perfect as elsewhere. This edge cover stays on until worn off and thus protects the fabric from the entrance of moisture which quickly deteriorates the whole belt and causes the thick top cover to peel off. *We make a good belt with a real edge.*

The B. F. Goodrich Company
Akron, Ohio

Jeffrey Conveyers

insure **Economy** and **Satisfaction**
in handling materials of all kinds

Drop a card for our conveying catalog K81



We build absolutely dependable conveying systems and quote the lowest prices consistent with the best materials and workmanship.

The Jeffrey Mfg. Company
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CONVEYING MACHINERY

for the mechanical handling of all materials.

Greatest Reliability.
Maximum Efficiency.

We will send to engineers upon request our 672 p. catalog which contains valuable data on the subject of conveying machinery

STEPHENS-ADAMSON MFG. CO.

164 Dearborn St.,
Chicago, Ill.
50 Church St.,
New York, N. Y.

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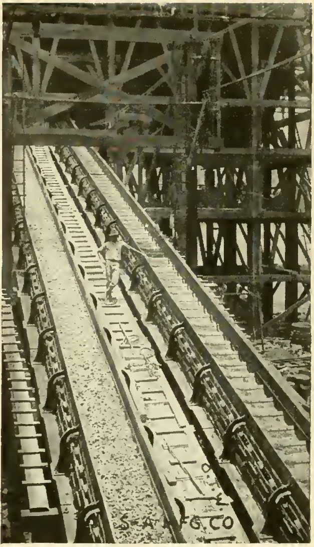


DIAMOND CHAIN MAKES SPLENDID FEED DRIVES

The two Diamond Chain Drives indicated in the accompanying cut of a 4½ in. by 30 in. Bardons & Oliver Turret Lathe are typical of many installations now driving parts of well-known American machine tools.

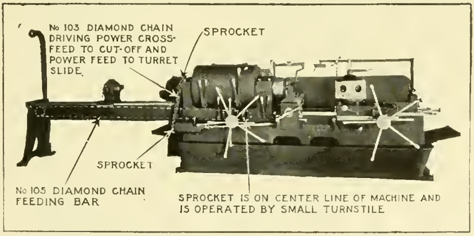
The conditions are especially favorable for Diamond Chains on automatic machines where accurate timing of operations to prevent interference with each other and where an absolutely reliable and positive drive are essential to good quality of product. The substitution of chain and sprockets for belted or friction drives in such instances not only increases the safety of the machine but increases the output sufficiently to pay for the change in a short time.

Tell us your transmission troubles and our engineers will tell you if chain offers the remedy.

DIAMOND CHAIN & MFG. CO.

259 W. GEORGIA ST. INDIANAPOLIS, IND.

Capacity 8,000,000 feet per hour


No 103 DIAMOND CHAIN DRIVING POWER CROSS-FEED TO CUT-OFF AND POWER FEED TO TURRET SLIDE
SPROCKET
SPROCKET
No 105 DIAMOND CHAIN FEEDING BAR
SPROCKET IS ON CENTER LINE OF MACHINE AND IS OPERATED BY SMALL TURNSTILE

"YELLOWSTRAND"
"POWERSTEEL" WIRE ROPE

The plain truth about wire rope

The are just two ways in the wide world to cheapen wire rope;

(1) Rush the rope through—kinks, twists, imperfections and all—or

(2) Substitute cheap material.

The buyer who insists on low prices forces the maker to one or both of these evils.

That is all there is to the cheapening problem—absolutely a-l-l.

Therefore the buyer of cheap ropes buys a liability to much trouble—much expense.

On the other hand, "YELLOW STRAND" ROPE stands first, last, always, for HONESTY, SAFETY, DURIBILITY.

And in the end it is vastly the CHEAPEST in the true sense of REAL ECONOMY.

If you don't want cheap rope, stipulate "YELLOW STRAND."
And demand that "YELLOW STRAND" appear on the invoice.

Ask for Catalogue No. 2.

BRODERICK & BASCOM ROPE CO.
ST. LOUIS, MO.

Works:	Branches:
St. Lious, Mo.	76 Warren St., New York
Seattle, Wash.	Seattle, Wash. San Francisco

THE STANDARD WIRE ROPE

MEAD-MORRISON
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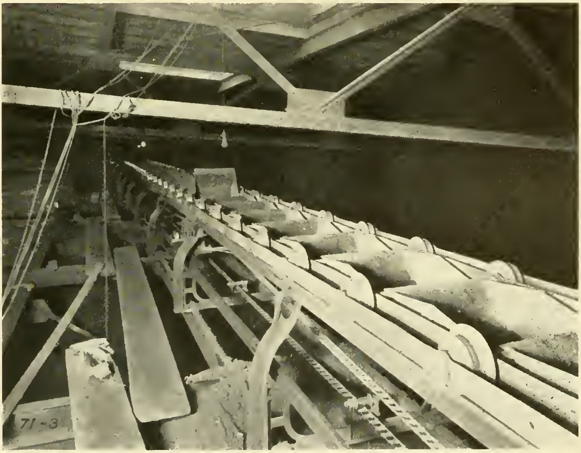

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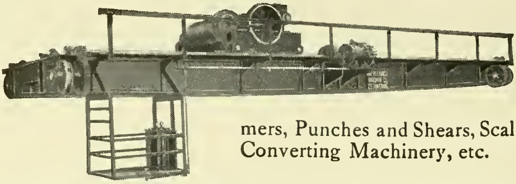

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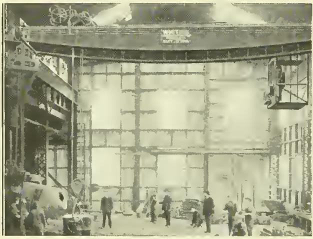

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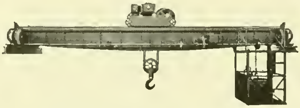

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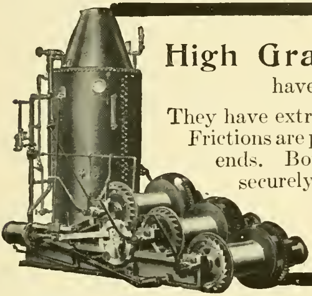

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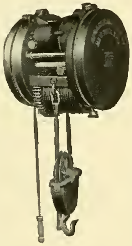

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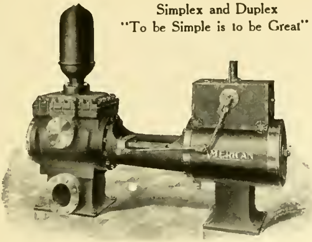

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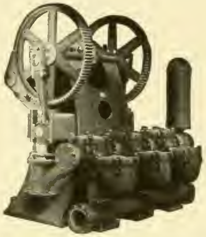

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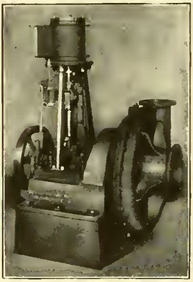

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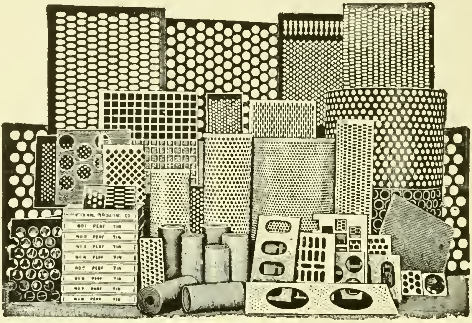

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ALPHABETICAL LIST OF ADVERTISERS

Page
Alliance Machine Co 26, 46
Allis-Chalmers Co...7, 19, 36, 42, 43
Almy Water Tube Boiler Co...... 34
American Engine Co..........14, 34
American Injector Co.........13, 37
American Pulley Co.............. 45
American Steam Gauge & Valve Mfg. Co....................... 37
American Steam Pump Co.....29, 43
Arnold Co., The................. 50
Ashton Valve Co................ 37
Atlantic Hydraulic Machinery Co. 43

Babcock & Wilcox Co.........11, 34
Baldwin, Bert. L................ 50
Ball Engine Co.............. .9, 34
Blaisdell Machinery Co.......... 44
Bridgeport Brass Co............ 37
Bristol Co.. 37
Broderick & Bascom Rope Co .24, 46
Brown Hoisting Mchy. Co...... 46
Bruce-Macbeth Engine Co...... 36
Buckeye Engine Co..........10, 34
Builders Iron Foundry........29, 43
Bulkley, Henry W............. 38
Butterfield & Co................ 31

Caldwell & Son Co., H. W....... 46
Carborundum Co 31
Carpenter Tap & Die Co., J. M..4, 31
Chapman Valve Mfg. Co.... 38
Chicago Pneumatic Tool Co..... 44
Cincinnati Gear Cutting Machine Co............................ 31
Cincinnati Shaper Co............ 31
Clarkson School of Technology... 50
Clyde Iron Works 27, 46
Conard, William R.............. 50
Crosby Steam Gage & Valve Co.. 38

Dallett Co., Thos H............ 45
Davidson Co., M. T............ 43
Dean, F. W.................... 50
Dearborn Drug & Chemical Wks. 38
De La Vergne Mach. Co......... 36
Diamond Chain & Mfg. Co...23, 45
Dixon Crucible Co., Joseph..14, 38
Dodge, Day & Zimmermann 49
Dodge Mfg. Co................. 45
Dodge Co., J. M............... 47

Page
Eastern Machinery Co.......... 47
Engineer Co., The.............. 38
Engineering Schools & Colleges.. 50
Erie City Iron Works............ 34
Exeter Machine Works.......... 41

Fellows Gear Shaper Co......... 31
Franklin Boiler Works Co....15, 34

Garvin Machine Co...........4, 31
General Electric Co..........18, 42
Goodrich Co., B. F...........22, 47
Goulds Mfg. Co..............29, 44
Goyne Steam Pump Co.......... 44
Grant Mfg. & Machine Co...... 32

Hammacher, Schlemmer & Co.... 32
Harrington & King Perforating Co..........................30, 49
Harrisburg Foundry & Machine Works........................ 35
Harrison Safety Boiler Works.... 38
Heine Safety Boiler Co........15, 35
Herrick, J. A................. 50
Hewes & Phillips Iron Works...9, 35
Hill Clutch Co.................. 45
Holyoke Machine Co.......... 44
Homestead Valve Mfg. Co...... 38
Hooven, Owens, Rentschler Co 15, 35
Hoppes Mfg. Co................ 39
Hughson Steam Specialty Co.. 39

Ide & Sons, A. L.............. 35

Jakobsson, Herman.............. 50
Jeffrey Mfg. Co.............22, 47
Jenkins Bros.................14, 39
Jones & Lamson Machine Co. 2, 3, 32

Keasbey Co., Robt. A............ 39
Kennedy Valve Mfg. Co......15, 39
King Machine Tool Co.......... 32

Laclede-Christy Clay Products Co............................ 39
Le Blond Machine Tool Co., R. K.. 32
Lidgerwood Mfg. Co............ 47
Link-Belt Co 47
Ludlow Valve Mfg. Co........ 39

Page
McCord & Co.................. 39
Main, Chas. T.................. 50
Manning, Maxwell & Moore.... 6, 32
Mead-Morrison Mfg. Co......25, 47
Mietz Iron Foundry & Machine Works, August................ 36
Model Stoker Co. 40
Monarch Valve & Mfg. Co...... 40
Morehead Mfg. Co............... 40
Morgan Engineering Co.......... 47
Morris Machine Works........29, 44
Murphy Iron Works...........7, 40
Murray Iron Works Co........12, 35

National Brake & Clutch Co..... 45
National Machine Co............ 32
National Machinery Co........6, 32
National Meter Co........... 11, 37
Nelson Valve Co...............8, 40
New Process Raw Hide Co... 5, 33
New York University School of Applied Science............... 50
Nicholson & Co., W. H......... 40
Niles-Bement-Pond Co........... 33
Northern Engineering Works..26, 48

Ohio Injector Co................ 40
Oneida Steel Pulley Co.......... 45
Otis Elevator Co.............21, 48

Paxson Co., J. W............... 49
Peterson, J. Wm................ 50
Polytechnic Institute of Brooklyn 50
Power Plant Specialty Co...... 40
Power Specialty Co............. 41
Pratt & Whitney Co............ 1
Professional Cards.............. 50
Providence Engineering Works.. 35

Quimby, Wm. E. Inc. 44

Reedy Co., H. J...............27, 48
Reliance Electric & Engrg. Co. 19, 42

Page
Rensselaer Polytechnic Institute. 50
Ridgway Dynamo & Engine Co. 13, 35
Robb-Mumford Boiler Co.... 12, 36
Rockwood Manufacturing Co ... 46
Roebling's Sons Co., John A..24, 48
Roots Co., P. H. & F. M......... 42
Ruggles-Coles Engineering Co.. 42
Russell, Burdsall & Ward Bolt and Nut Co...................6, 33

Scaife & Sons Co., Wm. B....... 41
Shaw Electric Crane Co........ 48
Simmons Co., John..........10, 41
Sprague Electric Co..........27, 42
Standard Roller Bearing Co...26, 49
Standard Tool Co.............. 6, 33
Stephens-Adamson Mfg. Co.. 23, 48
Struthers-Wells Co............11, 37
Sturtevant Co., B. F........... 42

Tight Joint Co................. 41
Tufts College 50

United Engineering & Foundry Co.........................5, 33

Wagner Electric Mfg. Co........ 43
Waltham Machine Works...... 33
Warner & Swasey Co.........1, 33
Webster Mfg. Co.............. 48
Westinghouse Electric & Mfg. Co..... ....17. 43
Westinghouse Machine Co....17, 36
Wheeler Condenser & Engrg. Co.. 41
Wheeler Mfg. Co., C. H........... 41
Whiting Foundry Equipment Co. 26, 49
Wiley & Russell Mfg Co........ 33
Wisconsin Engine Co..........7, 36
Wood's Sons Co., T. B........... 46

Yale & Towne Mfg. Co........21, 48

INDEX TO THE JOURNAL

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

JULY-DECEMBER, 1910

If it is desired to remove the index for the purpose of binding with The Journal for July to December, raise the staples upright, when the section will slip off easily. Then flatten the staples again.

INDEX TO JOURNAL JULY-DECEMBER, 1910

Note: Items appearing in The Journal as Society Affairs, have the month and page number given. Where the list of discussors of a paper is given, the list appears under the straight title of the paper. Papers published in The Journal previous to July, discussion of which was published during July to December, are indicated by the month followed by "1910." All papers, reports, etc., of the Gas Power Section appear under the heading Gas Power Section. Items regarding Student Branches are so indexed. Miscellaneous items are indexed under Miscellaneous.

American Locomotive Terminals, Wm. Forsyth 1231
Automatic Control of Condensing Water, B. Viola 1579
Ball-Bearing Lineshaft Hangers, Henry Hess .... May 1910
  Discussion
    F. B. Gilbreth, 1160 (Aug.); C. W. Baker, 1160; F. W. Dean, 1161; J. S. Bancroft, 1161; F. N. Van Derhoef, 1161; Harrington Emerson, 1162; Closure, 1163.
Battleship North Dakota, The United States, C. B. Edwards 1595
Belt Driving, A New Theory of, Selby Haar 1965
Boiler Efficiency, Combustion and, Edw. A. Uehling 2023
Bolton, R. P. *Operating Conditions of Passenger Elevators* 1983
Books, Current .... 1279, 1236 (Aug.), 1683, 1953, 2179
By-Laws, Amendment to .... Oct., 8
Clark, F. H. *Engine House Practice* 1219
Coleman, E. P. *First Large Gas-Engine Installation in American Steel Works* 1835
Combustion and Boiler Efficiency, Edw. A. Uehling 2023
Coming Meetings .... 1299, 1250 (Aug.), 1378, 1681, 1850 2176
Comparison of Lathe Headstock Characteristics, A, Walter Rautenstrauch .... June 1910
  Discussion
    C. G. Barth, 1655; Closure, 1657.
Condensing Water, Automatic Control of, B. Viola 1579
Condensation, Transmission of Heat in Surface, George A. Orrok 1771
Council Meetings
  May .... July, 61
  October .... Nov., 12
  December .... Dec., 12
Critical Speed Calculation, S. H. Weaver .... June 1910
  Discussion
    Henry Hess, 1359; S. A. Moss, 1360; M. Nusim, 1360; Closure, 1362
Economics of Railway Elecerification, W. B. Potter 1183
Edwards, C. B. *The United States Battleship North Dakota* 1595

Elastic Limit of Manganese and Other Bronzes, The, J. A. Capp..March 1910
  Discussion
    S. A. Moss, 1169 (Aug.); F. W. Dean, 1170; Closure, 1170.
Electric Driving in Machine Shops, Symposium on,
  See Symposium on Electric Driving
Elevators, Operating Conditions of Passenger, R. P. Bolton......... 1983
Employment Bulletin ....1283, 1241, (Aug.), 1369, 1674, 1941, 2164
Engineer's Duty as a Citizen, The, Geo. W. Melville..........(Aug.) 1127

Engines
  Engine-House Practice, F. H. Clark.......................... 1219
  Handling Engines, H. H. Vaughan.......................... 1241
  A Regenerator Cycle for Gas Engines Using Sub-Adiabatic Expansion, A. J. Frith.......................... 1247
England, The Joint Meeting in, Calvin W. Rice.......................... 1695
Experimental Analysis of a Friction Clutch Coupling, An, Wm. T. Magruder.......................... January 1910

  Discussion
    H. J. Smith, 1659; G. N. Van Derhoef, 1663; H. S. Smith, 1663; E. P. Haines, 1663; Oberlin Smith, 1663; Closure, 1664.
Field for Grinding, The, C. H. Norton.......................... 2113
Finance Committee, Annual Report..........................Dec., 20
First Large Gas-Engine Installation in American Steel Works, E. P. Coleman.......................... 1835
Forsyth, Wm. *American Locomotive Terminals*.......................... 1231
Freight Train Resistance, Edw. C. Schmidt ....May 1910

  Discussion
    T. S. Bailey, 1295; Wm. G. Raymond, 1296; S. A. Moss, 1299; F. W. Dean, 1299; H.G. Stott, 1300; G. N. Van Derhoef, 1300; F. J. Cole, 1301; W. F. M. Goss, 1303; J. B. Blood, 1304; Lawford H. Fry, 1307; Robert Moore, 1310; Chas. W. Baker, 1310; H. W. Hibbard, 1311; J. P. Clayton, 1312; F. W. Marquis, 1312; Closure, 1312.
Frith, A. J. *A Regenerator Cycle for Gas Engines Using Sub-Adiabatic Expansion*.......................... 1247
Gantt, H. L. *The Mechanical Engineer and the Textile Industry,* (Aug.) 1127
Gas Engines for Driving Alternating-Current Generators, H. G. Reist, June 1910

  Discussion
    P. M. Lincoln, 1291; Closure, 1293.
Gas-Engine Installation in American Steel Works, First Large, E. P. Coleman.......................... 1835
Gas Engines Using Sub-Adiabatic Expansion, A Regenerator Cycle for, A. J. Frith.......................... 1247
Gas Power Section
  Preliminary Report of Literature Committee.......................... 1267
Gas Producer, Notes on a Heavy-Duty, Nisbet Latta.......................... 2079
Gearing, Interchangeable Involute, Wilfred Lewis.......................... 1631
Graphical Method for Calculating Stresses in a Connecting Rod, A, Winslow H. Herschel.......................... 1609

Grinding
  The Field for Grinding, C. H. Norton.......... 2113
  Precision Grinding, W. A. Viall.......... 2127
  Modern Grinding Methods, B. M. W. Hanson.......... 2139
Haar, Selby. *A New Theory of Belt Driving*.......... 1997
Hadaway, J. B., M. B. Kaven and. *Modern Shoe Manufacture*.......... 1961
Handling Engines, H. H. Vaughan.......... 1241
Handling Locomotives at Terminals, F. M. Whyte.......... 1203
Hanson, B. M. W. *Modern Grinding Methods*.......... 2139
Harter, Isaac, Jr. *Notes on the Value of Napier's Coefficient with Superheated Steam*.......... 2017
Heat in Surface Condensation, Transmission of, George A. Orrok.... 1771
Herschel, Winslow H. *A Graphical Method for Calculating Stresses in a Connecting Rod*.......... 1609
House Committee, Annual Report..........Dec., 26
Improved Absorption Dynamometer, An, C. M. Garland..........March 1910
  Discussion
    C. M. Allen, 1166 (Aug.); Closure, 1167.
Interchangeable Involute Gearing, Wilfred Lewis.......... 1631
John Fritz Medal Award..........Nov., 7
Joint Meeting in England, The, Calvin W. Rice.......... 1695
Kaven, M. B. and Hadaway, J. B. *Modern Shoe Manufacture*.......... 1961
Kiln, The Rotary, Ellis Soper.......... 1563
Latta, Nisbet. *Notes on a Heavy-Duty Gas Producer*.......... 2079
Lewis, Wilfred. *Interchangeable Involute Gearing*.......... 1631
  Discussion
    P. V. Vernon, 1644; C. R. Gabriel, 1645; Luther D. Burlingame, 1649; Daniel Adamson, 1651; Thomas Humpage, 1652; R. M. Neilson, 1654; J. R. Williams, 1654.
Library
  Accessions to ....1280, 1237 (Aug.), 1365, 1671, 1934, 2159
  Annual Report of Committee ....Dec., 27
Locomotives
  Handling Locomotives at Terminals, F. M. Whyte.......... 1203
  Engine House Practice, F. H. Clark.......... 1219
  American Locomotive Terminals, Wm. Forsyth.......... 1231
  Handling Engines, H. H. Vaughan.......... 1241
Machine Shops, Symposium on Electric Driving in.
  See Symposium on Electric Driving
Mechanical Engineer and the Textile Industry, The, H. L. Gantt...May 1910
  Addition..........(Aug.) 1127
Meeting in England, The Joint, Calvin W. Rice.......... 1695
Meetings Committee, Annual Report..........Dec., 27
Meetings of the Society
  English Meeting..........July, 3, Aug., 3, Sept., 3, 1695
  Spring Meeting..........July, 7
  Annual Meeting..........Nov. 4, Dec. 3
  May: St. Louis,..........July 5
  June: Boston,..........July 6

MEETINGS OF THE SOCIETY—Continued
  October: New York, Oct., 3,; Nov. 5; Boston, Oct., 3; Nov. 7; San Francisco, Nov., 6; St. Louis, Nov., 7
  November: New York, Nov., 3; Dec., 9; Boston, Nov., 3; Dec., 10; St. Louis, Nov., 4, Dec., 11
  December: Boston, Dec. 9; St. Louis, Dec. 9
MEETINGS OF OTHER SOCIETIES
  American Boiler Manufactures Association.................... 1931
  American Chemical Society ....(Aug.) 1233
  American Gas Institute.................... 1930
  American Institute of Chemical Engineers.................... 1273
  American Institute of Electrical Engineers, 1274, 1229, (Aug.) 1928, 2152
  American Institute of Mining Engineers, Sept 16, 1274, 1927, Oct. 7, 2151
  American Iron and Steel Institute.................... 1930
  American Society for Testing Materials....................(Aug.) 1232
  American Society of Civil Engineers, 1229 (Aug.), 1364, 1665, 1927, 2152
  American Society of Engineering Contractors.................... 1667
  American Society of Municipal Improvement.................... 1929
  American Society of Naval Architects.................... 1273
  American Railway Association.................... 1275
  American Street and Interurban Railway Association.................... 1931
  American Waterworks Association 1272
  Association of Railway Electrical Engineers.................... 1668
  Brooklyn Engineers Club.................... 1929
  Canadian Electrical Association....................(Aug.), 1233
  Colorado Electric Light and Railway Association.................... 1668
  Engineers Club of St. Louis. 1929
  International Congress of Refrigeration.................... 2153
  International Railway Master Blacksmiths' Association.................... 1364
  National Association of German-American Technologists.................... 1667
  National Association of Master Sheet Metal Workers 1363
  National Association of Manufacturers.................... 1272
  National Electric Light Association.................... 1272
  National Machine Toolbuilders Association....................1274, 2152
  National Society for the Promotion of Industrial Education (Aug.).................... 1231, 2154
  New England Waterworks Association.................... 1667
  New York Electrical Society.................... 2155
  New York Railroad Club 1667
  Ohio Electric Light Association....................(Aug.) 1233
  Roadmasters and Maintenance of Way Association.................... 1668
  Society for the Promotion of Engineering Education....................(Aug.) 1231
  Society of Automobile Engineers.................... 1364
  Society of Naval Architects and Marine Engineers.................... 2155
  Western Railway Club.................... 1275
MELVILLE, GEO. W. *The Engineer's Duty as a Citizen*.................... 1127
MEMBERSHIP
  Membership, Changes in .....1287, 1243 (Aug.), 1371, 1676, 1944 2167
  Membership Committee, Annual Report....................Dec., 31

Methods for Calculating Stresses in a Connecting Rod, A Graphical, Winslow H. Herschel 1609
Miscellaneous
  American Museum of Safety 2152
  Conservation Congress .... 1233 (Aug.), Oct., 6
  Courses in Architecture in Engineering Societies Building 1928
  Dedication of Forests Products Laboratory .... (Aug.) 1230
  Director of New Bureau of Mines .... Oct., 7
  Illuminating Engineering Courses at Johns Hopkins University 1275
  International American Scientific Congress 1274
  International Congress of Mining, Metallurgy and Practical Geology 2153
  International Hunting Congress .... (Aug.), 1230
  International Railway Congress 1363
  National Irrigation Congress 1928
  Opening of the Fritz Engineering and Coxe Mining Laboratories at Lehigh University .... (Aug.) 1230
  Tribute to Dr. Raymond .... Nov., 9
Modern Grinding Methods, B. M. W. Hanson 2139
Modern Shoe Manufacture, M. B. Kaven and J. B. Hadaway 1997
Naphtaly, Sam. L. *Test of a 10,000-kw. Steam Turbine* 2089
Necrology
  Mark Bary .... Aug., 11
  Clay Belsley .... Nov., 16
  Jonas H. Bloomberg .... July 25
  James W. Bridge .... July, 23
  Charles B. Clark .... Oct., 14
  William E. Crane .... Sept., 19
  Barton Cruikshank .... Nov., 15
  John D. E. Duncan .... Sept., 17
  Ralph Waldo Emerson .... Aug., 11
  James B. Faulks, Jr. .... Sept., 18
  Charles A. Ferry .... Oct., 14
  Joseph Garbett .... Oct., 15
  Frederick Bellows Hall .... Dec., 17
  Washington Jones .... Dec., 18
  Walter Craig Kerr .... July, 21
  John E. McKay .... Oct., 12
  William N. Parsons .... July, 25
  Francis J. Plummer .... July, 23
  Charles T. Porter .... Oct., 9, Nov., 8
  Iltyd I. Redwood .... July, 24
  Stillman W. Robinson .... Dec., 18
  William W. Snow .... Sept., 18
  Ernest P. Sparrow .... July, 24
  Albert Spies .... Oct., 11
  Frederick M. Wheeler .... Nov., 15
  Alfred Wilkinson .... Nov., 17
New Theory of Belt Driving, A, Selby Haar 1965
Norton, C. H. *The Field for Grinding* 2113

Notes on a Heavy-Duty Gas Producer, Nisbet Latta 2079
Notes on the Value of Napier's Coefficient with Superheated Steam, Isaac Harter, Jr. 1961
Operating Experiences with a Blast-Furnace Gas-Power Plant, H. J. Freyn .... June 1910
  Addition 1319
  Discussion
    A. E. Maccoun, 1322; Joseph Morgan, 1333; H. G. Stott, 1336; E. A. Uehling, 1336; S. K. Varnes, 1337; H. G. H. Tarr, 1343; Edward Rathbun, 1343; Jesse M. Smith, 1343; C. W. Baker, 1344; E. P. Coleman, 1344; A. Bement, 1345; W. E. Snyder, 1345; Closure, 1353.
Operating Conditions of Passenger Elevators, R. P. Bolton 1983
Orrok, George A. *Transmission of Heat in Surface Condensation* 1771
Parker, G. R. *Discussion on Steam Engine Turbine Unit* .... Aug. 1157
Personals .... 1276, 1234 (Aug.), 1365, 1669, 1934, 2156
Potter, W. B. *Economics of Railway Electrification* 1183
Precision Grinding, W. A. Viall 2127
Publication Committee, Annual Report .... Dec., 32

Railway Electrification
  The Electrification of Railways, George Westinghouse 1133
  Economics of Railway Electrification, W. B. Potter 1183
Regenerator Cycle for Gas Engines Using Sub-Adiabatic Expansion, A, A. J. Frith 1247
Research Committee, Annual Report .... Dec., 34
Rice, Calvin W. *The Joint Meeting in England* 1695
Rotary Kiln, The, Ellis Soper 1563

Roundhouse Practice
  Electrification of Trunk Lines, L. R. Pomeroy .... February 1910
  The Electrification of Railways, George Westinghouse 1133
  Economics of Railway Electrification, W. B. Potter 1183
  Handling Locomotives at Terminals, F. M. Whyte 1203
  Engine House Practice, F. H. Clark 1219
  American Locomotive Terminals, Wm. Forsyth 1231
  Handling Engines, H. H. Vaughan 1241
Soper, Ellis. *The Rotary Kiln* 1563
Shoe Manufacture, Modern. M. B. Kaven and J. B. Hadaway 1961
Steam, Notes on the Value of Napier's Coefficient with Superheated, Isaac Harter, Jr. 2017
Steam Turbine, Test of a 10,000-kw., Sam. H. Naphtaly 2089
Steel Works, First Large Gas-Engine Installation in American, E. P. Coleman 1835
Strength of Cast-Iron Punch and Riveter Frames, The, A. L. Jenkins, May, 1910
  Discussion
    James Christie, 1259; Walter Rautenstrauch, 1262; Frank I. Ellis, 1269; Henry Hess, 1270; Oberlin Smith, 1271; Wilfred Lewis, 1272; John S. Myers, 1273; S. A. Moss, 1277;

George Westinghouse, 1278; E. J. Loring, 1279; Closure, 1280.
Stresses in a Connecting Rod, A Graphical Method for Calculating, Winslow H. Herschel.......... 1609

Student Branches
  Brooklyn Polytechnic..........Dec., 15
  Columbia University..........July, 18
  Cornell University..........July, 18
  Massachusetts Institute of Technology..........July, 18; Nov., 11
  Pennsylvania State College..........July, 18; Nov., 10
  Purdue University..........July, 19; Nov., 10; Dec., 15
  Stanford University..........July, 19; Nov., 10
  Stevens Institute of Technology..........July, 19; Nov., 10
  University of Cincinnati..........July, 19; Dec., 15
  University of Illinois..........Nov., 11; Dec., 16
  University of Maine..........July, 19
  University of Missouri..........July, 20; Nov., 10
  University of Nebraska..........July, 20
  Wisconsin University..........July, 20; Nov., 11; Dec., 16
  Yale University..........Nov., 11
Superheated Steam, Notes on the Value of Napier's Coefficient with, Isaac Harter, Jr.......... 2017
Symposium on Electric Driving in Machine Shops, A. L. DeLeeuw, November, 1909; Charles Robbins, April 1910; John Riddell, April 1910.
  Discussion
    M. L. Holman, 1189 (Aug.); W. F. M. Goss, 1189; E. R. Fisk, 1190; A. H. Timmerman, 1191; P. A. Morse, 1192; H. H. Humphrey, 1193; O. Stephensen, 1193; Wm. H. Bryan, 1194; H. Wade Hibbard, 1194; Charles Fair, 1195; Henry Hess, 1195; L. R. Pomeroy, 1205; Gano Dunn, 1209; Fred. L. Eberhardt, 1210; A. L. DeLeeuw, 1212; Carl G. Barth, 1215; John Riddell, 1215; H. A. Hornor, 1216; W. S. Chase, 1217; Clarence L. Collens, 1217.

Terminals
  American Locomotive Terminals, Wm. Forsyth.......... 1231
  Handling Locomotives at Terminals, F. M. Whyte.......... 1203
Test of a 15,000-kw. Steam-Engine Turbine Unit, H. G. Stott and R. J. S Pigott..........March 1910
  Addition..........Aug., 1129
  Discussion
    W. L. R. Emmet, 1137; Max Rotter, 1139; E. F. Miller, 1143; Edw. L. Clark, 1144; E. D. Dreyfus, 1146; Chas. P. Steinmetz, 1148; J. W. Lieb, Jr., 1153; D. S. Jacobus, 1153; B. R. Shover, 1154; G. R. Parker, 1155; O. Junggren, 1155; F. Samuelson, 1156; Closure, 1156, 1665; G. R. Parker, 1157.
Test of a 9000-kw. Turbo-Generator Set, F. H. Varney.......... 2105
Test of a 10,000-kw. Steam Turbine, Sam. L. Naphtaly.......... 2089

Testing of Water Wheels after Installation, The, C. M. Allen......April 1910
  Discussion
    R. A. Hale, 1172 (Aug.); J. C. Parker, 1176; Dwight Porter, 1178; G. E. Russell, 1179; H. K. Barrows, 1180; H. D. Jackson, 1181; H. C. Daggett, 1184.
Tooth Gearing (in abstract), J. D. Steven........................... 1643
  For discussion see Interchangeable Involute Gearing
Transmission of Heat in Surface Condensation, George A. Orrok.... 1771
Two Proposed Units of Power, Wm. T. Magruder...............June, 1910
  Discussion
    Wm. Kent, 1313; E. D. Dreyfus, 1316; H. G. Stott, 1316; I. Lungaard, 1317; Closure, 1317.
Turbines
  Test of a 10,000-kw. Steam Turbine, Sam L. Naphtaly............. 2089
  Test of a 9000-kw. Turbo-Generator Set, F. H. Varney........... 2105
Turbo-Generator Set, Test of a 9000-kw., F. H. Varney.............. 2035
Uehling, Edw. A. *Combustion and Boiler Efficiency*.................. 2023
United States Battleship North Dakota, The, C. B. Edwards.......... 1595
Varney, F. H. *Test of a 9000-kw. Turbo-Generator Set*.............. 2105
Vaughan, H. H. *Handling Engines*..................................... 1241
Viall, W. A. *Precision Grinding*..................................... 2127
Viola, B. *Automatic Control of Condensing Water*.................. 1579
Water, Automatic Control of Condensing, B. Viola................ 1579
Westinghouse, George. *The Electrification of Railways*........... 1133
Whyte, F. M. *Handling Locomotives at Terminals*................. 1203

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